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VOL. XXVI, NO. 3 JULY, 1944 Old Series Vol. XLII, No. 3

The Journal of Bone and Joint Surgery

RECONSTRUCTIVE SURGERY TODAY

INTRODUCTION*

BY ARTHUR G. DAVIS, M.D., ERIE, PENNSYLVANIA

The challenge of the immediate future is nothing more than the challenge Medicine has repeatedly faced in the past, following war's devastation.

Many noble but largely futile attempts have been made to save the severely wounded arms and legs of veterans from the amputation block. Today a new vista opens in reconstructive surgery of the extremities. The recent emergence of chemotherapy has brought about this brighter prospect and makes necessary a complete revision of outlook. Penicillin and the sulfonamides, by controlling the element of infection, open the way to the control of the various other factors responsible for the delay or arrest of the normal healing process. This is revolutionary. The horizons thus opened up beckon to the reconstruction surgeon. We have the right to say *here and now* that we can with assurance approach hitherto forbidden fields, because of the safeguard afforded by these drugs. The infected compound wound with bone, nerve, tendon, or skin defect needs no longer to form an almost insurmountable barrier to the reconstruction surgeon.

This group of papers has for its purpose the charting of a new course in a field of endeavor as yet little known. Past concepts must be largely abandoned, except as they afford a background of technical experience. The bad results of reconstructive surgery following the last War must not be permitted to blur the very hopeful perspective we now have a right to adopt.

The following revisions, therefore, seem important at this time in the reconstructions of extremities representing various defects of the bony framework.

1. New means are at hand to create optimum wound-healing.

   a. With the use of plasma and whole blood, a hemoglobin of nearly 100 per cent. may easily be attained, and this is fundamental to all phases of the healing and bone-repair process.

   b. The use of penicillin completely safeguards the patient against local contamination and bacteriemia.

   c. Control of the increased interstitial-fluid volume is a prerequisite to surgical interference.

   d. Provision through the massive use of blood transfusion or high protein, high-

*Introduction to the program of the afternoon session, June 2, 1944, at the Annual Meeting of The American Orthopaedic Association, Hot Springs, Virginia.

caloric diet, or both, must be made for the hypoproteinaemia so conspicuous in depleted states.

2. Creation of the vascular bed essential to callus formation.

a. A solidly healed wound is an absolute prerequisite to all reconstruction. The proper preparation of the patient by the new means already enumerated provides a tremendously accelerated wound-healing rate.

b. Skin plastic replacement of surface defects is completely essential, regardless of how well the subsequent surgery is done.

c. Deep, thorough-going resection of scar is a necessary preliminary to the creation of an ideal bone-graft bed.

d. Appropriate physiotherapy and functional use of the part involved, whenever possible, still further increases the vascular bed and is an essential preliminary.

With such preparation of the part and the person, one has a right to attempt the bridging of defects which, in the past and without the advantage of adequate preparation, would have required amputation of the extremity.

We of the middle-age group need to guard against the conservatism naturally engendered by the conditions and restrictions of our early training. The amputation knife always had to be ready to sacrifice the part, in order to preserve the individual. These restrictions no longer exist as a threat to surgical interference. The new orientation calls for at least a trial at salvage in healed compound infected wounds, rather than the hopeless sacrifice of the part Because of the prevention of virulent wound infections in the advanced battle zone, together with the certainty of their prevention when subsequent surgical reconstruction is attempted, it is clear that the values in the field of reconstruction surgery have been reversed in the hiatus between wars. We can in fact be justly criticized, if at least one consistent attempt under present accepted minimal conditions of procedure is not made, before amputation, particularly in the case of lesions of the upper extremity and in cases where but one lower extremity remains.

THE BASIC PROBLEMS IN BONE-GRAFTING FOR UNUNITED COMPOUND FRACTURES*

BY CLAY RAY MURRAY, M.D., NEW YORK, N.Y.

From the Department of Surgery, College of Physicians and Surgeons, Columbia University, and the Fracture Service of the Presbyterian Hospital in the City of New York

The over-all purpose of bone-grafting for ununited compound fracture is simply stated,—it is the bridging by living bone of a variable gap between the bone fragments.

As corollaries to this simply stated fact, however, certain other purposes must guide our procedure:

1. It is essential that the bone used for grafting ultimately be fully incorporated as an integral part of the host bone into or on which it has been placed, and that it continue permanently to exist as such.

2. Dependent upon functional demands, it may be desirable or essential that considerable new bone form and persist in the tissues surrounding the graft.

3. Dependent again upon functional demands, length and alignment adequate to meet those demands must be preserved during the period preceding grafting, or restored at the time of grafting.

4. The control of infection—active, or potential and latent—is essential.

The accomplishment of these various purposes entails the solution of a number of basic problems in a definite chronological sequence. Since these problems are all concerned with the purpose of forming new bone in the human adult, it may be well, before we consider them, to set down briefly and as simply as possible, what takes place when new bone is formed in the human adult. In so doing I shall attempt to avoid all discussion of matters of academic interest or dispute, and shall attempt to limit the description of the process to data of practical importance. From a practical standpoint it is valueless to discuss such moot questions as whether a bone graft actually continues to live when transplanted, or dies and is replaced; whether bone formation is the result of the activity of a specific cell known as the osteoblast, or is a process independent of such specific cell activity; whether the so-called matrix and the calcium which ossifies it are inseparable and must come and go together, or whether the mechanisms involved in the deposition or removal of each are entirely independent; and what is the source of the phosphatase which is involved in calcium deposition. Let us rather put down in the briefest manner the demonstrable facts of practical value.

1. New-bone formation in the human adult takes place only in newly formed, undifferentiated connective tissue. It does not occur in fully differentiated fibrous connective tissue.

2. The formation of bone in this tissue requires an adequate local concentration of utilizable calcium and, what is probably of more importance, phosphate.

3. The presence of a ferment, phosphatase, is seemingly needed to accomplish the deposition of the locally concentrated calcium in the undifferentiated tissue to form bone. Its action is apparently that of splitting up phosphoric esters to free the phosphate radical for combination with the calcium and organic radicals.

4. A pH in the local tissue fluids within the range in which the phosphatase is active is required. Its optimum pH is well to the alkaline side,—above 8.0; but it is decreasingly active to the acid side,—above 6.0. In lower pH ranges it is inactivated. Following tissue trauma such as occurs with fracture (accidental or operative), the pH in the local tissue fluids can be accurately demonstrated to fall as low as 4.2, a pH at which the phosphatase concerned is completely inactive.

*Read at the Annual Meeting of The American Orthopaedic Association, Hot Springs, Virginia, June 2, 1944.

5. The formation of new bone in the human adult may then be said to depend upon an adequate local concentration of utilizable calcium and phosphate in newly formed, undifferentiated connective tissue, in the presence of a phosphatase at a pH level in the tissue fluids which will allow of adequate activity of the ferment. All these conditions must coexist. If the pH of the local tissue fluids remains so low as to predicate a minimal phosphatase activity while the newly formed tissue is differentiating, a slow deposition of calcium—or delayed union—occurs. If it remains so low as to preclude phosphatase activity until the newly formed tissue is differentiated, a so-called non-union—really a union by differentiated fibrous tissue—occurs. If the rise in the pH of the tissue fluids toward the average (or so-called normal) pH of 7.2 or 7.3 is rapid, the formation of bony callus will be rapid, all other factors being equal.

6. The amount of new bone thus formed will depend upon the amount of newly formed undifferentiated tissue available for ossification. The permanency and density of the new bone will be dependent upon three known factors: the density of the original local concentration of calcium and phosphate and a continuation of the supply of calcium and phosphate sufficient to equal the amounts withdrawn from the bone by the mechanisms of body metabolism; the maintenance of tissue-fluid reactions in and in contact with the bone at adequate levels for the continuing deposition of calcium; the stresses and strains to which the newly formed bone is consistently subjected.

7. The amount of undifferentiated connective tissue to be ossified will be in proportion to the available sources, and will be influenced as well by the factors which influence all wound healing,—serum-protein levels, vitamin status, local circulatory status, blood volume, hemoglobin, electrolyte balances, *et cetera*.

8. The source of supply of calcium and phosphate is initially in great measure the bone itself, which releases calcium into the surrounding tissue fluids in the presence of, and proportionate to, the lowered pH in those fluids. Ultimately it is the general metabolic mechanism.

9. The creation of a suitable pH level in the local tissue fluid depends upon the status of the general metabolic mechanism, on the local piling up of autolysates of tissue death and of the products of cell metabolism, and on the relative efficiency of available local minute circulation (that of the tissue spaces, the lymphatics, and the ultimate capillaries) in dispersing the products of the autolysis of tissue death, hemorrhage, and exudate, and of the products of cell metabolism.

10. The presence of normal muscle tone, the size and richness of the capillary bed, normal muscle action without spasm or clonus, the absence of undue tissue tension, and the effect of gravity are potent factors in maintaining efficient minute circulation.

11. The local accumulation of acid products is furthered (*a*) by any inflammatory process in proportion to its severity, be it due to mechanical (that is continual movement at the fracture site), chemical (infection or chemically irritant foreign bodies), or thermal (such as excessive milliamperages of diathermy) stimuli; (*b*) by muscle spasm which hampers the minute circulation; (*c*) by mechanical interference from outside the body, such as undue compression of the tissues, or the tourniquet action of a bandage fold or suspension band; (*d*) by meagerness of vessels in the capillary bed; (*e*) by undue tension within the tissues; (*f*) by massive or continued tissue death.

There are innumerable fields for discussion in the foregoing statements on bone repair, but neither time nor space allows of detailed amplification. However, we can all agree in general on this concept of what goes on during the bone-healing process in the adult, although we might argue as to details or as to the whys and wherefores. It is essential that we regard bone-grafting as the deliberate establishment by surgical procedures of the optimum conditions which we would desire present in any fresh fracture. In any case the basic problem is that of new-bone formation following trauma.

Let us revert to the chronological order of the problems we face in grafting for non-union in compound fractures. They may be stated as:

1. The preoperative elimination of any active local infection of bone or soft part, and the creation of safeguards against any postoperative flare-up of latent infection.

2. The maintaining or regaining of as much of necessary length and alignment as possible preoperatively, in order that the ultimate operative procedure may be simplified, and the operative site may be under as little mechanical strain as possible. This is a problem of the mechanics involved in the individual case.

3. The next problem to be met is that of replacing the differentiated type of fibrous connective tissue which joins and envelops the bone ends, by newly formed and undifferentiated connective tissue, rich in collagen. This must be provided in the presence of a readily available and vascularizable local source of calcium and phosphate, under conditions in the minute circulation of the part which will allow these materials to be incorporated in the new tissue before it differentiates into formed fibrous connective tissue.

4. The final problem is the continued maintenance of the newly formed bone.

In order to ensure optimum chances of success, the solution of these basic problems must take cognizance of the individual, of the condition of bone and soft parts at the site of the proposed procedure, and of the procedure itself.

A surgeon often reports a certain type of graft successful in all of a series of cases, although in some instances the procedure may have had to be repeated two, three, or more times before ultimate success was attained. Such a viewpoint, centering entirely upon the ultimate success of a technical operative procedure, is not calculated to ensure success beyond the law of chance in any individual procedure. All types of grafts are ultimately successful in at least a large percentage of cases, if not in all, according to the results reported by many of the proponents of the various types. If this be true, the type of graft is a matter of indifference. Why all the heated discussion anent the advantages of one type over another? The really vital point is not the number of cases ultimately grafted successfully, but the number of unsuccessful procedures; and these must be analyzed from the standpoint of why they were unsuccessful, if we are to learn anything from those failures. The answer frequently lies, we may be certain, in unconsidered factors in the individual and in the local conditions, and not in the type of graft used. The major factor in failure is often the adoption of a standard routine for all cases, concentrating on the type of graft as the essential element.

The optimum chance of attaining our major purpose in doing bone grafts for the ununited compound fracture should be ensured by attacking the basic problems presented along the following lines.

Preoperative

1. By systemic attack on local active infection, or on latent potential infection, by attention to such factors as blood volume and hemoglobin, and by the systemic use of chemotherapy.

2. By local attack on active infection, through adequate drainage, complete removal of dead or infected bone or foreign bodies, and local chemotherapy. This would seem to be vital to the assurance of success in the control of infection.

3. By allowing sufficient time to elapse between apparent complete control of infection and of complete wound-healing, and further operative procedures—an essential safety factor for optimum chance of success.

4. By attention to the systemic factors affecting the healthy healing of wounds by undifferentiated connective tissue,—blood volume, hemoglobin, serum-protein levels, vitamin status, *et cetera*.

5. By plastic procedures, if need be, long enough after control of infection and suf-

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ficiently in advance of the bone-grafting, to provide organized sources of new, undifferentiated connective-tissue growth, and to augment locally deficient minute circulation.

6. By improvement in efficiency of the local minute circulation through attention directed to muscle tone by exercise and active use, by physiotherapeutic substitutes for these, by pressure dressings or supports, and by positional (Buerger exercise) and gravity aid.

The use of a brace to allow active exercise for some weeks or months preliminary to the grafting procedure may mean the difference between success and failure. An atrophic and flabby extremity which has been inactive in plaster for months, is not an ideal subject for a bone-grafting procedure.

Operative

1. By removal of formed connective tissue (scar) from between and about the bone fragments, or by sufficient destruction of it, to allow replacement by new vascular undifferentiated tissue. This would include the removal of, or drilling of, sclerotic dense bone down to or into healthy vascular sources of minute circulation and new-tissue growth.

2. By soft-part plastic procedures, where indicated to augment local minute circulation and to provide a source for growth of undifferentiated tissue.

Everything up to this point has been concerned with the creation of a proper environment for the graft. The importance of proper planning, and of proper timing, of the various procedures in meeting the problems involved cannot be overemphasized.

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3. The placing of a graft of adequate size in the environment prepared for it in such manner that it can be most easily and competently vascularized and invaded by newly formed, undifferentiated connective tissue.

4. The rigid fixation of the graft and of the fracture fragments. Whether one uses internal fixation of the graft, the fracture fragments, or both, or external fixation by plaster, pin and plaster, pin and apparatus, or any other method, or a combination of internal and external fixation, it is essential that rigid fixation of graft and of fracture site be secured. If this is not accomplished, movement at the graft site or at the fracture site may cause a varying degree of local inflammatory reaction. With the associated local minute circulatory congestion and stagnation, this may lead to calcium absorption, failure of calcium deposition, or undue slowness of calcium deposition, resulting in a delayed ossification or a failure with actual absorption and disappearance of the graft.

Postoperative

1. Continuation of the systemic attack on possible latent infection and the safeguarding against any deficit in the systemic factors involved in wound-healing.

2. The continuance of rigid fixation of the graft and of the fracture site until solid bony healing is secured.

3. The cultivation of optimum efficiency in the minute circulation of the part, utilizing normal muscle exercise with or without joint movement, physical therapy, soft-part pressure support, and postural means to the fullest extent which the necessary immobilization of the graft and fracture site will allow.

4. The progressive use of adequately safeguarded functional strain as soon as unquestioned incorporation of a viable graft into the host bone is assured.

Only certain of these problems may exist in the individual case, but the optimum chance of success will lie in the recognition of those which do have to be dealt with, and in the properly planned and timed attack on each one. It is unquestionably true that successful bone-grafting can and often does result when the rationale here outlined is ignored in one or in many respects. It may even be necessary, by reason of circum-

stances, to depart from it more or less widely. The basic principles involved are sound, however, and the chances of successfully handling the great numbers of expected war casualties of this type, many with extensive loss of substance, will be greatly enhanced by a rational system of analysis of the individual problems presented, as a basis for a planned and timed schedule of therapy.

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WOUND-HEALING IN COMPOUND FRACTURES AND REPAIR OF BONE DEFECTS *

BY CAPTAIN KARL F. MECH

Medical Corps, Army of the United States

The frequent occurrence of severely traumatized extremities, with comminution of bone, resulting often in bone defects and non-union, seen in military wounds and accidents, as well as in industrial and high-speed-vehicle accidents, creates a grave problem for the orthopaedic surgeon. The immediate care of the patient and the care of the extremity must include not only the saving of life and limb, but also the restoration of maximum function to the injured part as soon as possible.

The care of infection and the healing of the wound is of utmost importance, and the sooner these can be accomplished, the earlier are effected the repair and the return of function of the part. In the cases where any reparative or reconstructive operation is planned, it is believed that the infection must first be controlled and the wound completely healed. In the cases seen not too long after injury, much can be accomplished in achieving early wound-healing. This is true even after the contamination period has passed. The use of the newer antibacterial agents in conjunction with good surgery often makes the difference between early healing and chronic infection. Débridement with the open-wound method of treatment, followed by plaster-of-Paris or traction fixation, and with other necessary treatment such as blood replacement and good nutrition, will result in early healing.

In cases of long-existing suppurating wounds, with the patient showing the systemic effects of chronic sepsis, the treatment is a little more difficult and requires a longer period of time. The depletion of the patient, sometimes extensive, and his impaired faculty for control of infection and healing of wounds make him a problem differing greatly from the early case.

A word may be said at this point concerning the new antibacterial agents now in general use. Of the great number that have been produced in the last decade or so, only the sulfonamides and penicillin have been accepted for general use, and these remarks will be limited to a discussion of these two therapeutic agents.

* Read at the Annual Meeting of The American Orthopaedic Association, Hot Springs, Virginia, June 2, 1944.

The sulfonamides will be dismissed with only a few remarks, because of their widespread use, the extensive literature, and the familiarity of all with the subject. The sulfonamides have found a useful place in the treatment of these cases. Especially in war surgery, it is felt that the open-wound method of treatment, with the routine use of sulfonamides, has resulted in a great saving of life and limb, even though many infections are seen after their use. The modification and control of the early fulminating infection have meant the saving of many limbs that might have been lost. The fact that these drugs are not ideal and do not do the entire task of eliminating infection does not in any way relegate them to disuse, but it does encourage us to keep seeking for a more effective agent.

The question of the local use of sulfonamides is still a subject of discussion with good authority on both sides. In wounds with adequate blood supply, the systemic administration should be sufficient protection for the patient. However, if the drugs are properly used locally, no particular harm should be done. Powder or crystals of sulfanilamide or sulfathiazole, or mixtures of the two, have been used by many workers, sometimes along with buffers and other substances such as urea. Some claim has been made for the greater efficacy of the sodium salts of these compounds as local agents. Local therapy may do good in selected cases. Systemic therapy is given both orally and intravenously; the intravenous method is reserved usually for the immediately postoperative period. Sulfathiazole and sulfadiazine are the drugs most frequently used, and a sufficient amount is given to maintain a fairly high blood level. While sulfonamide therapy is usually effective, it is not without its drawbacks. The occasional failures, not infrequent toxic reactions, and the gastro-intestinal upsets, with depression of appetite in some instances, interfere with the proper care and nutrition so essential in these cases.

In some contrast to this, penicillin has been found to be a more potent antibacterial agent, active against almost all of the common pathogenic organisms found in traumatic wounds, and almost completely non-toxic.[6, 8] There are no contra-indications to its use, but it should be realized that it is active chiefly against the gram-positive organisms and the gram-negative cocci, and is not effective against the other bacteria. Since most wounds contain organisms that fall into the susceptible group, penicillin should be effective. It is of benefit in mixed infections. Even in susceptible species, an occasional organism is found to be resistant to penicillin. This can be determined by testing the organisms *in vitro* against penicillin. The intramuscular route of administration is usually employed, since this method has proved very efficient, and is the one which can be used by nursing personnel without special care or training. Intravenous administration is used in selected cases which require rapid and constant concentration of penicilln in the blood and tissues. Subcutaneous administration is painful, and the rate of absorption is inconstant; so we prefer not to use this route.

Specific dosage schedules have been laid down for different groups of organisms, in pure culture, varying with their susceptibility to penicillin; but unfortunately, rather than containing a pure culture of a single organism, most wounds are found to be polymicrobial in character. In these wounds, the higher doses are recommended for routine use—usually 200,000 units per day, divided into eight doses of 25,000 each, given every three hours—although some men claim effective treatment with 120,000 units per day. It has been our practice to use a dose which may be too large; but, since we are dealing with a severe infection and a drug in which the dosage has not been standardized, we prefer too large a dose rather than one too small to be effective, for it is definitely known that penicillin is relatively non-toxic. Penicillin is still expensive, but certainly to be effective it must be used in adequate doses. Local therapy is often carried on in wounds, which are of such a nature as to allow this use, in combination with systemic therapy. Duration of treatment follows no set rule. The absence of the systemic manifestations of sepsis—such as fever, fast pulse, and leukocytosis—together with local criteria—such as disappearance of local oedema due to cellulitis—and the covering by healthy granulations of all

exposed cortical bone are all factors to be considered. Fortunately, very few reactions have ever been observed with penicillin, and these are never severe; urticaria is the only one seen at our Hospital for a long time, and this only occasionally.

Most patients with compound fractures of long standing have wounds which are not ideal from the standpoint of drainage or local therapy. Most of these wounds contain sequestra and some contain foreign bodies. It is our experience that such wounds cannot be sterilized and healed until this debris has been removed. However, these patients are often in too poor general condition to allow any extensive manipulation or surgery. Lyons has aptly described this "unsteady state" and its treatment in patients treated at our Hospital. Almost constant findings in the severe infections of compound fractures were the following: weight loss (often as much as sixty-five to seventy pounds), loss of appetite with very low intake of food, anaemia, low blood pressure, and general debility. On further study, the patient was found to be in negative nitrogen balance, the blood volume was very definitely reduced, and the interstitial-fluid volume was definitely increased. The susceptibility of these patients to shock is readily understood in view of these findings, particularly in view of the diminished effective blood volume. Since surgery is often urgently required, this condition has to be corrected as rapidly as possible. The blood level does not stay up, even after replacement, unless sepsis is controlled and nutrition is maintained.

Cuthbertson has pointed out marked losses of nitrogen, sulphur, and phosphorus in the urine of otherwise healthy individuals, who are in receipt of moderate or serious traumatic injury, beginning the day after injury and reaching the maximum about ten days later. The greater the injury, the greater the loss. He notes also a wasting of muscle and bone out of proportion to that expected with immobilization, and interprets this to mean that the body is catabolizing its reserves to meet the exigencies of repair and maintenance, rather than eliminating the products of disintegration in the damaged tissues. He states, "The ingestion of diets very rich in first-class protein and of high-caloric value by persons suffering from the fracture of one or more of their long bones as the result of direct violence, modifies considerably the marked loss of body protein which normally occurs under such circumstances." He makes the interesting statement that high-protein diet alone does not make positive nitrogen balance. Our findings are consistent with this observation.

Whipple, in his scholarly address on wound-healing, gives among others the following factors affecting wound-healing: The amount of killed or damaged tissue, vascularity and integrity of the blood flow, the amount and character of the exudate in the wound space and tissues bordering the wound, the number and character of infectious organisms in the wound space and bordering tissues, and the number and character of the foreign bodies to be extruded or encapsulated. In addition to these, he specifically enumerates systemic factors which affect wound-healing. These include: age of the tissues; state of normal hydration which is determined by water, electrolyte, and protein balance in the blood; normal nutritional balance in which protein deficiency retards and high-protein diet accelerates wound-healing, and high-fat diet prolongs the repair of wounds; vitamin balance, particularly for the effect of vitamin C in the formation of the fibroblast and the transformation of fibrous to collagen fibers; and the state of the general circulation and blood picture in which poor circulation and severe anaemia definitely alter or delay wound-healing.

Baker, some years ago, in discussing the factors concerned in wound-healing, pointed out the importance of glutathione and hemoglobin in fibroplastic proliferation.

Ravdin and his associates have pointed out the effect of hypoproteinaemia on the healing of wounds, with the high incidence of wound disruption in hypoproteinaemic dogs, with complete control by large amounts of plasma.

Kernwein demonstrated the total absence of callus formation in experimental fractures in rabbits on complete starvation.

Rhoads likewise points out the slowness with which bony callus is formed after experimental fracture in dogs depleted of protein and plasma. He points out that not only is the plasma protein deficient, but so also is the "labile protein reserve". In addition, he suggests that possibly the serum calcium and serum protein may be tied together. He concludes that severe hypoproteinaemia retards the formation of bony callus in fractures produced in dogs by the section of the ulna with a Gigli saw.

Thus in the cases studied, our findings were consistent with those of the authors quoted above. The deficiencies were notably in blood volume, hemoglobin, and blood and tissue proteins; other deficiencies were the result of these.

The blood volume in the cases under study was determined by the Evans blue-dye method as described by Gregersen. Replacement of the deficient volume can be quickly accomplished by plasma or whole blood. The figures found on this determination indicate that our previous efforts in replacement fell short, because we never gave sufficient blood. Many patients had deficiencies of as much as 2,000 cubic centimeters of whole blood. At least the same amount as the deficiency is required to restore the volume quickly to normal. Since there is a concomitant deficiency of hemoglobin, whole blood is used, because we have no real substitute for hemoglobin. Plasma plus iron helps in the restoration, but the process is rather slow, and so is useless where rapid replacement is desired. Control of infection by penicillin aids in the maintenance of the level of the blood, since a constant fall occurs while there is sepsis.

Another interesting finding reported by Lyons, the significance of which is not well understood, is that of an increased volume of interstitial fluid. Why this should coexist with a lowered blood volume is not easily understood, and the answer is not yet known. This is evidently another evidence of the grave upset in the total metabolism of the patient in sepsis. With improvement in sepsis, the interstitial-fluid volume slowly returns to normal.

The loss of weight, the great decrease in muscle mass and strength, and the decrease in the protein concentration, all point to a decrease in the available proteins. When the decreased concentration is further considered, along with the decreased blood volume, the true deficiency is found to be even greater than was apparent at first. Since hypoproteinaemia and lowered labile protein reserve have been shown to have such a profound effect on the healing of wounds, every effort should be made to prevent or correct this state as rapidly as possible. While much has been said about the administration of blood and plasma, and while these are a great aid in supplying utilizable protein, as shown by Ravdin, this is an uneconomical way of accomplishing the positive nitrogen balance. With the great increase in appetite which usually follows the administration of penicillin, and with the efficient control of sepsis, diet can commonly be depended upon to supply sufficient protein, especially when the protein is protected by carbohydrate and fat in the diet to prevent the burning of protein for energy. Special high-caloric, high-protein diets are used for these patients, and dietetic care is exercised in the preparation and serving of the food so that each patient is given to understand that this represents one definite part of his treatment. We have had no trouble feeding our patients 2,500 to 3,000 calories or more per day. Protein is maintained at 150 grams or more per day in this diet. Elman and others have demonstrated the efficiency of protein hydrolyzates in maintaining the positive nitrogen balance, especially in those patients who are not able to eat normally. With only brief experience with this substance, it was concluded that in the patient already taking a rather good diet, little if anything was added, since excretion often mounted with the increased intake. However, with patients not willing or able to take a full diet, Elman's method may be of great assistance. In our cases, diet alone has been sufficient to create a positive nitrogen balance, when infection is controlled by penicillin.

The program of surgical management of these septic cases then would be as follows:

The patient is studied and his condition is determined.

Penicillin is started in order to decrease the effects of the sepsis.

Whole-blood transfusions are given in such amounts as are necessary to restore the blood to its normal level. In clinical practice it may not be possible or even desirable to do the blood-volume determination on every patient. In that case, no single laboratory test will give that information and the surgeon must estimate the need by what laboratory work may be done, plus his best clinical judgment. If any error is to be made, let it be on the side of using too much blood rather than too little.

High-caloric, high-protein diet is given to the patient and the part is prepared for operation.

When the condition seems to be optimal, usually in two to five days or longer, operation is performed, and all necessary surgery is done. Dead bone and foreign bodies are removed, devitalized tissue is excised, and the wound is revised, so as to bring about adequate externalization. The wound is then usually left open with a light vaseline-gauze pack. Occasionally, in selected cases, reduction of a fracture in poor position may be accomplished.

Blood and plasma are used at the time of operation and during the immediate postoperative period. Usually these wounds are not dressed for from three to seven days, in order to avoid too much bleeding in the fresh wound.

Systemic penicillin is given during these days, and is sufficient to take care of infection during this time. After the early dressings, if the progress is satisfactory, systemic penicillin is discontinued, and local application to the wound is carried on until wound-healing has occurred or secondary closure is done.

Under such a program, the general health of the patient is usually rather rapidly improved, with normal blood level and content, and positive nitrogen balance. The wounds take on a healthy appearance, fill in very satisfactorily, and heal or may be closed in a relatively short time.

After complete wound-healing, the patient is sent to a convalescent ward. At this time he may be seen by the plastic surgeon, if any extensive scar is present. If a skin-plastic operation is necessary, penicillin may or may not be employed to avoid a recurrence of the infection. If penicillin is used, it is started a day or two prior to the operation, and is continued usually for about five days postoperatively. It is our practice to relieve all extensive skin defect, and this is particularly true if the patient is to require a secondary reconstructive procedure. Following the skin-plastic operation, the patient is again sent to the convalescent ward.

The time interval for skin healing is calculated from this time. This period of waiting is important as a test of true healing without infection, and allows for consolidation of the scar and re-establishment of the circulation. A great difference of opinion exists as to its duration. With the use of penicillin at the time of the reconstruction operation, Carpenter and Rosenfeld at this Clinic have determined three months to be a favorable time in many cases. Penicillin is employed before and after the operation, and has proved to be effective in preventing reinfection. If so short an interval is used, it is strongly advised that a good antibacterial agent be employed, and at present penicillin is the most effective one in use.

SUMMARY

Penicillin has been used clinically and found to be effective in controlling most wound infections associated with compound fracture, when used in full doses as an adjunct to a well-rounded surgical program. As an effective dose, 200,000 units per day, given by the intramuscular route, in 25,000-unit doses every three hours each twenty-four hours, is recommended. Since most patients with septic compound fractures require operative procedures, the "unsteady state" described by Lyons must be corrected rapidly, and whole blood and plasma are the only agents which quickly accomplish this. High-protein,

high-caloric diet is used for adequate supply of proteins needed for the repair of tissue. Wound-healing is most satisfactorily effected under a combination of good surgical care—including operation with the patient supported by blood and plasma therapy—adequate diet, and control of infection by penicillin therapy. With the patient in good condition, and with the use of penicillin in the prevention of infection, reconstructive surgery can be performed at a shorter interval of time after complete wound-healing than was formerly considered safe.

CONCLUSIONS

Wound-healing in compound fractures is most satisfactorily obtained by an adequate surgical program which includes the use of penicillin in the control of infection, and a thorough consideration of the patient's general nutritional status. The latter calls for particular attention to the patient's needs for blood, plasma, and a diet high in protein and calories.

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SURFACE REPAIR OF COMPOUND INJURIES *

BY JAMES BARRETT BROWN

Lieutenant Colonel, Medical Corps, Army of the United States

When definitive bone, tendon, or nerve repairs have been done deep in wounds, the results can only be as good as the surface healing. Surface healing can be only as good as the deep blood and nerve supply. Wounds that are excessively fibrotic, and have a diminished blood supply, often cannot maintain the nutrition of their own skin covering,

FIG. 1-A

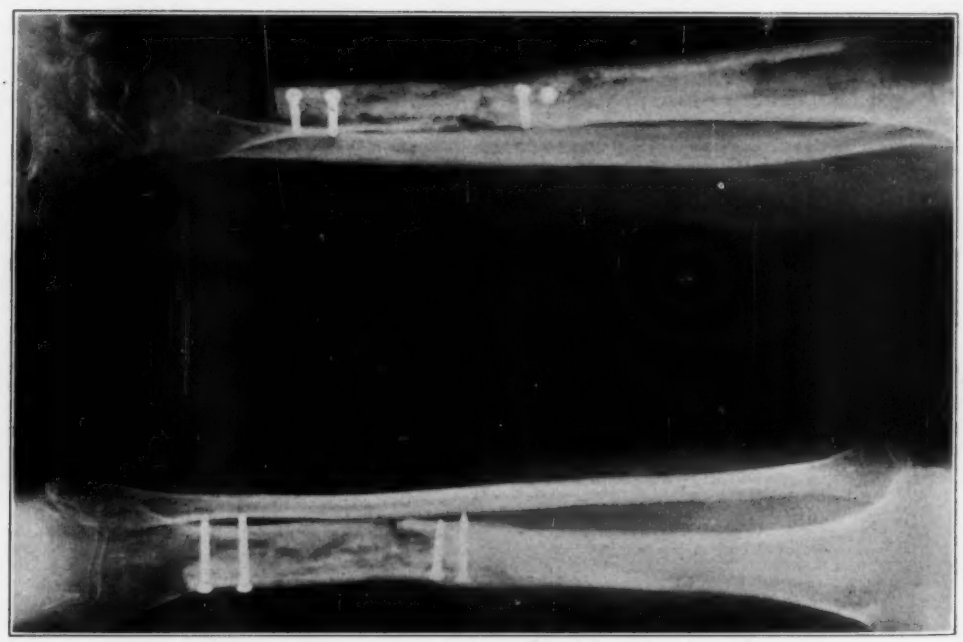

FIG. 1-B

Result of unsuccessful attempt at bone-grafting through dense scar.

* Read at the Annual Meeting of The American Orthopaedic Association, Hot Springs, Virginia, June 2, 1944.

FIG. 2-C

FIG. 2-B

FIG. 2-A

Gunshot wound of thigh, repaired with a free, thick, split-skin graft. Further necessary surgery may now be performed.

NOTE: It has been found that gunshot and shell-fragment injuries usually require pedicle-flap repairs, as shown in Figures 3-D and 5.

Fig. 3-A

Fig. 3-B

Fig. 3-C

Resultant deformity and open wound, following unsuccessful bone graft through scar tissue so dense that the wound had broken down.

Resultant deformity and open wound, following unsuccessful bone graft through scar tissue so dense that the wound had broken down.

FIG. 3-D

Same forearm after extensive resection of scar and application of a direct flap from the abdominal wall.

NOTE: The use of direct rather than tubed or delayed flaps saves several operations and weeks of hospitalization. The direct, immediate flap can be designed so as to accurately fit the defect. The extent of the defect is only possible of estimation when the scar is excised at operation. It is, of course, recognized that delayed or tubed pedicle flaps may be necessary when the donor site is not close to the recipient.

FIG. 3-E

FIG. 3-F

Finished flaps on the forearm after seventeen days on the abdomen.

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and a newly transplanted surface over such a wound may not survive. This is seen repeatedly in radiation burns and in chronic leg ulcers. The same conditions are also seen in gunshot and shell-fragment wounds where badly and extensively torn tissues have healed (or attempted to heal) in contracted, dense scar masses, the surfaces of which repeatedly ulcerate. Such wounds may have rough, keratotic surfaces. This may be especially true in "through-and-through" injuries, because the track of scar tissue completely penetrates the area, so that, in a dissection, the surgeon does not encounter a soft, normal bed of tissue.

The factors that have to be balanced in planning satisfactory wound closures in preparation for some subsequent bone, nerve, or tendon repair are, briefly: (1) the preparation of deep tissues to carry adequate blood supply for the *surface* repairs, through the resection of surface and deep scar, continued into an area that will furnish satisfactory circulation,

FIG. 4-A

FIG. 4-B

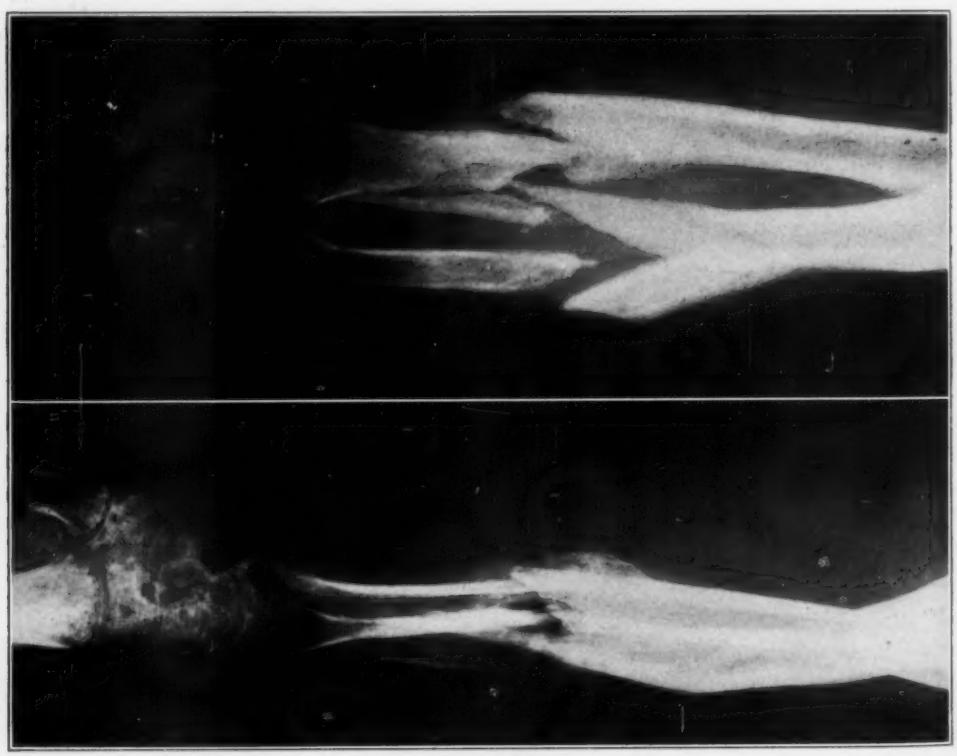

FIG. 4-C

Healed through-and-through gunshot wound. (For method of surface repair used, see Figs. 6-A, 6-B, 6-C, and 6-D.)

NOTE: It is recognized that little or no definitive deep surgery can be successfully carried out in such densely scarred areas.

and (2) the designing of a surface closure through the use of local flaps, skin grafts, or direct or delayed pedicle flaps.

There are also multiple secondary problems that must be considered,—such as the preservation of all possible sensory nerve supply, especially in the feet and hands, and the selection of a donor site that will avoid added crippling. For example, if a damaged leg is to be repaired for partial restoration of function, and it is recognized that the other leg will always have to do more than its share of work, then nothing should be taken away from this leg that can be avoided. Different regions of the body require completely different considerations; a lesion of a few square centimeters on the sole of the foot or over the malleolus may be refractory to treatment, and may produce permanent disability, whereas a defect of even a square foot on the thigh or body may rather easily be repaired.

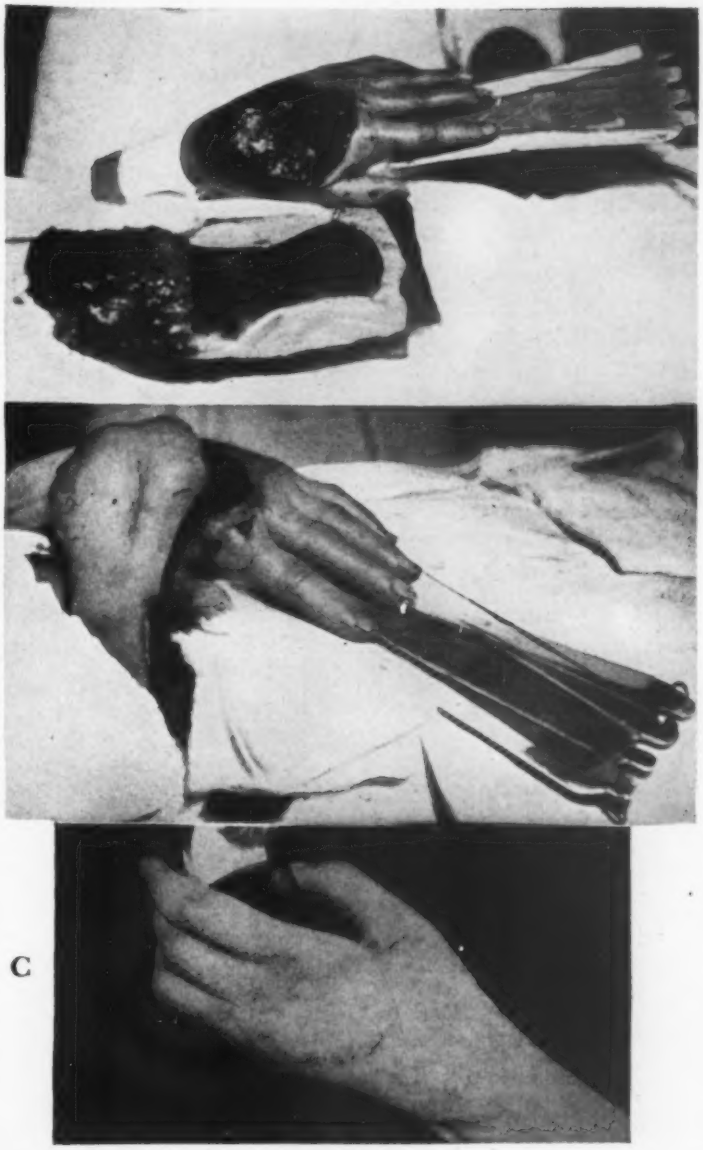

FIG. 5

Gunshot, through-and-through wound of hand. Patient came to Hospital for amputation, but a direct abdominal flap was put in place eight days after the injury, and the final result is far better than any prosthesis. (The simple aluminum splint, with a thumb "cut out" to keep the thumb rotated opposite the fingers, follows the recommendations of Kanavel, Koch, and Mason.) (*Reproduced from Skin Grafting of Burns*[1] *by courtesy of J. B. Lippincott Company.*)

It is hardly necessary to say that, in any extensive repair, the general physical and mental condition of the patient is of extreme importance, and must be right before the work is begun. This may require the correction of protein deficiency, anaemia, and other malnutritional states (especially underweight), and the control of diseases, such as malaria, which deplete the white blood cells.

Lower-leg wounds are notoriously difficult to repair, and are becoming more notorious all the time; some that seem relatively simple may keep patients off duty for months, and repairs, if attempted, may complicate rather than alleviate. These wounds are especially important in the Services, as limitation in walking is extremely annoying, and makes for

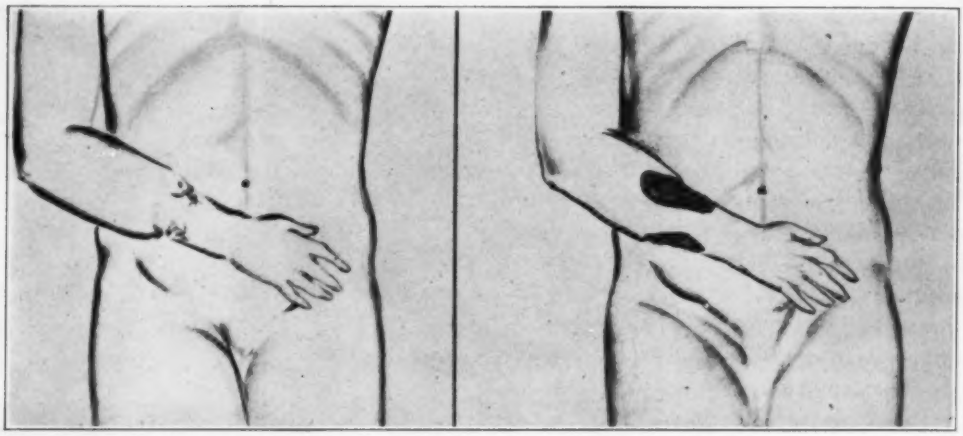

FIG. 6-A

FIG. 6-B

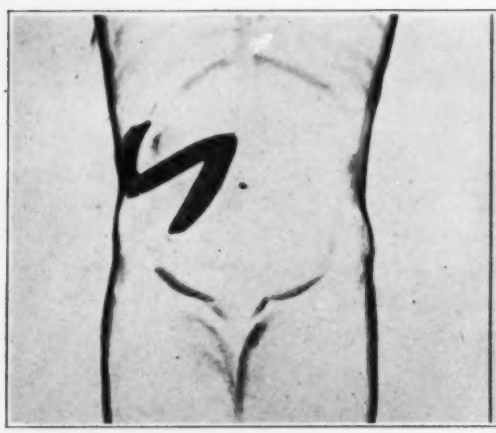

FIG. 6-C

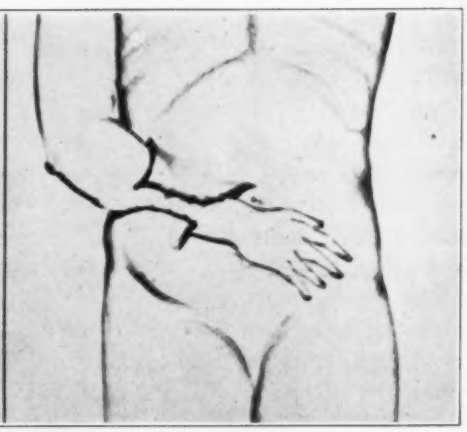

FIG. 6-D

Showing the method of using double abdominal flaps. The flap for the volar surface is taken with the base of the flap up; that for the dorsal surface with the base of the flap down. This might be called a "double V" or "lazy N". (This is the method which was used in the gunshot wound, shown in Figs. 4-A, 4-B, and 4-C.)

recurrent and excessive waste of man power. The status of a lesion in the soldier is often the reverse of that in the civilian,—that is, a man who had lost an eye could be of more service to the Army than one who couldn't get around because of some small lesion on his foot, while this same foot lesion might go almost unnoticed in civil life and occupation.

These are perhaps simple considerations, but they are very important in the best utilization of man power, as well as in the determination of what surgical procedure to attempt. It is possible that much time and debility could be saved, in many patients, by the early application of flaps, as in the case shown in Figure 5.

NOTE: This work has been done in association with Captain Bradford Cannon, Major Spencer Snedecor, and Captain Walter Graham.

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BRIDGING OF BONE DEFECTS IN COMPOUND WOUNDS*

BY JOHN ROYAL MOORE, M.D., PHILADELPHIA, PENNSYLVANIA

Four principal problems confront the surgeon in the bridging of bone defects in compound wounds: (1) infection; (2) skin and scar defects; (3) faulty local and general physiology; and (4) successful bone-grafting.

The papers of this group, which have just been read by Dr. Murray, Captain Mech, and Colonel Brown, have dealt with the first three of these problems. The elimination of infection, the repair of skin and scar defects, and the restoration of normal physiology *converts the compound fracture into a simple fracture in the literal sense. The conversion of the compound fracture into a simple fracture is a prerequisite for successful grafting of bone defects.* Since bone-grafting is the principal means of repairing defects in bone, it seems pertinent at this time to review our fund of knowledge on this important phase of the subject.

Salient Historical Data.

Hippocrates (460 B.C.) believed that bones, cartilage, tendons, nerves, *et cetera*, did not unite by reproduction, but that union occurred by foreign tissue.† It was Galen (130 A.D.) who presented the theory of the osseous fluid as an agent in bone repair. According to his theory, the ends of bone did not unite, but were solidified by this fluid, which was thrown out, and which was none other than a nourishing fluid, peculiar to bone, and supplied by the blood stream itself. Even in the fifteenth, sixteenth, and seventeenth centuries, there was no departure from the Galenic theory. It was Havers, an anatomist, in 1692, who gave the first accurate account of the osseous structures. He also discovered the vascular canals of the bony system, to which posterity has attached his name (Haversian system). It remained for another investigator in the nineteenth century to complete the study of the vascular system as we now know it (von Volkmann). In 1736, Belchier reported the peculiar staining of bones in madder-fed ‡ pigs and chickens. In this con-

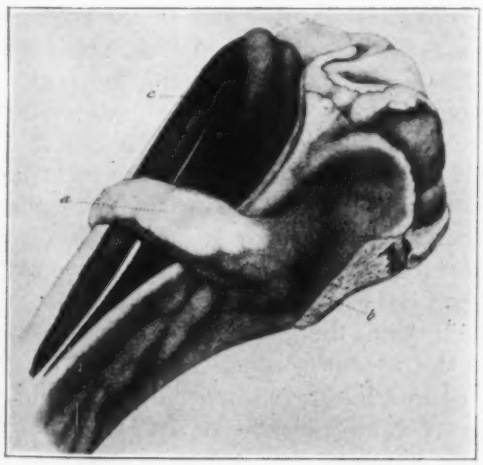

FIG. 1-A

Ossification of a portion of the tibial periosteum of a dog. (*Reproduced from Ollier, opposite p. 72.*)

FIG. 1-B

Heterotopic bone obtained by transplanting a portion of the periosteum taken from the tibia of a chicken. (*Reproduced from Ollier, opposite p. 80.*)

* Read at the Annual Meeting of The American Orthopaedic Association, Hot Springs, Virginia, June 2, 1944.

† *Os quum persectum fuerit aut cartilago aut nervus, aut genae particula tenuis, aut praeputium, neque augetur neque coalescit.*

‡ Madder: the root of the rubbia tinctoria affording a red dye.

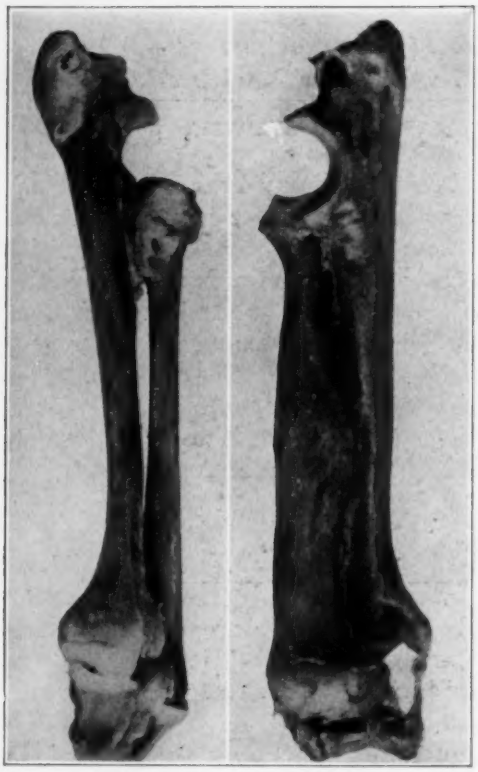

FIG. 2-A FIG. 2-B

Fig. 2-A: Left radius and ulna, not operated upon.

Fig. 2-B: Right radius and ulna. The radius had been operated upon twelve weeks previously. The entire periosteal covering was removed at that time, and a one-inch section of bone removed. The gap resulting from the removal was packed with small fragments of bone removed from another dog. Note the complete restoration of continuity, but overgrowth of shaft, especially marked at the site of section. (*Reproduced from Macewen, p. 77.*)

tribution lay the foundation for the fundamental work on osteogenesis which was to follow. Duhamel, in 1741, noted that madder stains only growing bone. He described the two layers of the periosteum—the supporting and the osteogenic—and named the latter "cambium,"† a term which has persisted to this day. He also demonstrated the peripheral growth of bone (subperiosteal lamination). John Hunter, in 1746, working with madder-fed animals, proved that bones grow in length at the ends. Ollier, in 1867, ascribed bone regeneration to the periosteum. His periosteal-tube transplantation and the resultant periosteal ring is a classical experiment. Later, Ollier agreed that the periosteum forms bone only in growing bones and occasionally in adult bone; his work marks the beginning of the osteoblastic theory of bone formation. Wolff (1836–1902) presented the first law concerning the physical changes in bone. "All changes in function are accompanied by alteration in bone morphology." The knowledge of this law is fundamental to the understanding of bone repair in massive bone defects, as well as bone pathology.

About this same period, Roux in 1881 called attention to the fact that osteogenesis in fractures and defects of bone depends upon bone contact (called the law of frictional irritation). Bone contact is one of the requisites in bone-grafting. Barth, in 1893, noted that, in spite of the smooth healing of bone grafts, the greater part of the bone graft actually undergoes necrosis and replacement. This concept is identical with the one held at the present time. Axhausen, in 1898, demonstrated the fact that the bulk of the bone graft dies, but that the subperiosteal and endosteal surfaces of the graft are capable of regeneration. This observation, incidentally, is the basis for the present general usage of the autogenous bone graft. Macewen, in 1912, proved conclusively that osteoblasts coming from the endosteum and the subperiosteum (superficial cortical layer) of bone are responsible for repair, and that the periosteum is useless, unless the underlying surface layer of the cortex is attached in some degree (basis for the present osteoperiosteal graft).

The importance of the technique employed in bone-grafting reached its height in 1911 with Albee's contribution of the motor saw. Albee's experience with tree-grafting taught him the significance of the accurate fit of the scion or graft (homologous layers), complete immobilization, and a suitable bed. He felt that there was an analogy between tree-grafting and bone-grafting, and evolved the principles of bone-grafting which are the basis of present-day technique. His employment of the massive tibial bone graft in the fusion of a tuberculous spine not only marked the advent of the massive bone graft, but also presented the earliest great contribution to bone-graft surgery. In 1913, Brown contributed further information, thus confirming the laws of Wolff and Roux,—namely,

†Cambium: a layer of cells between bark and wood.

FIG. 3-D

Result thirty years later. (*Reproduced from Macewen, p. 189.*)

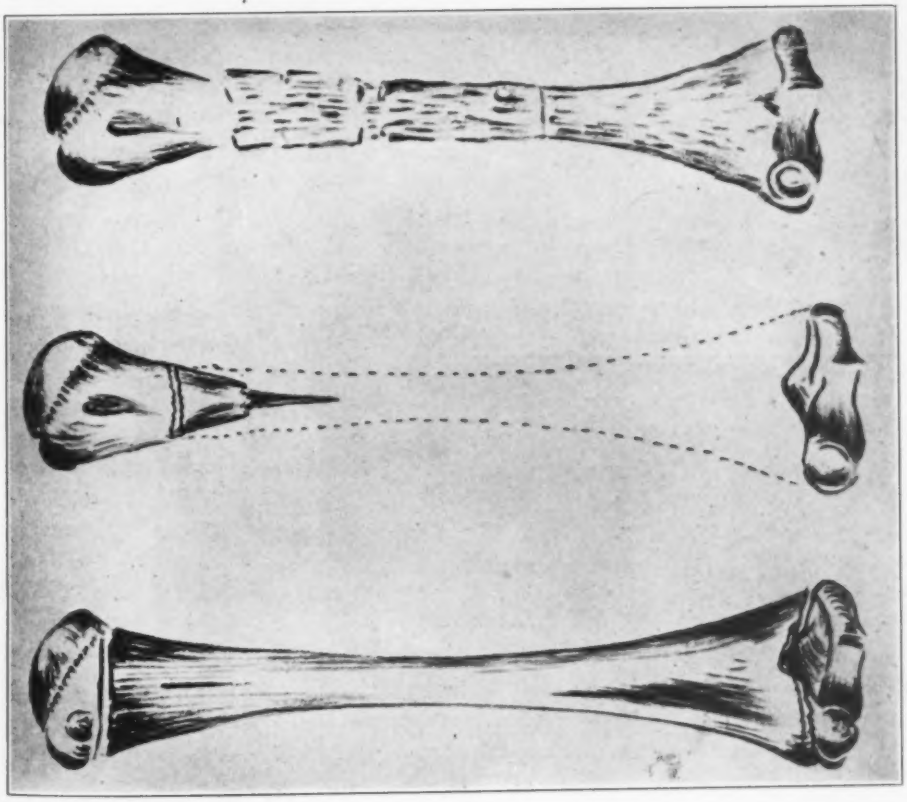

FIG. 3-A FIG. 3-B FIG. 3-C

Fig. 3-A: The diaphysis, which was necrosed and removed.
Fig. 3-B: The result fifteen months later, showing the absence of the shaft.
Fig. 3-C: The result of the completion of the grafts. (*Reproduced from Macewen, p. 177.*)

FIG. 4-A

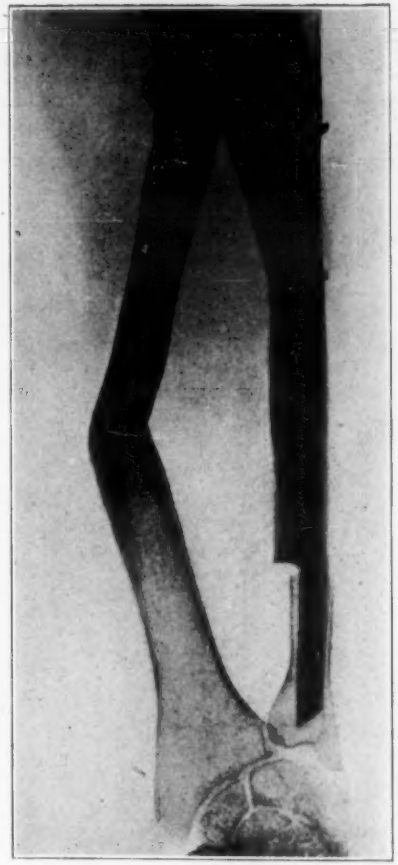

FIG. 4-B.

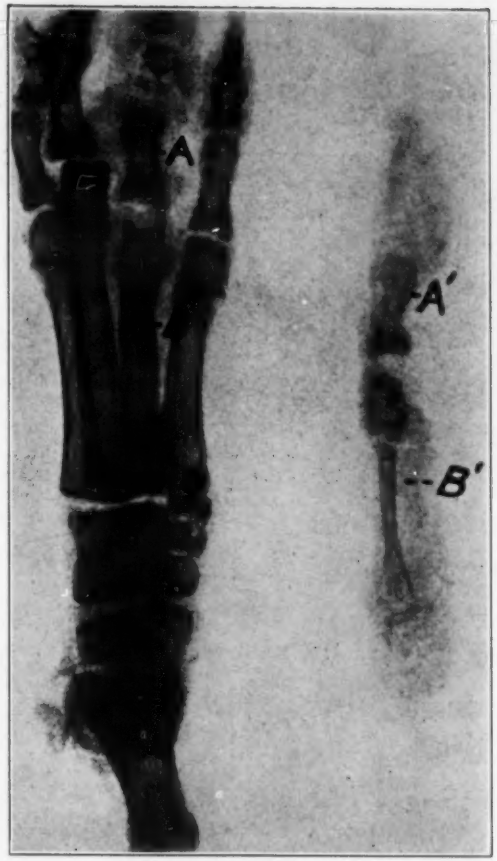

FIG. 5-A FIG. 5-B

Fig. 4-A: There is a malunion of the radius and a large gap in the ulna. (*Reproduced from Jones, p. 178, by permission of the Oxford University Press.*)

Fig. 4-B: Showing the same bones after operation. As the radius was displaced away from the ulna, it was left alone. The ulna was united by a long tibial graft, pegged into the lower fragment, and united to the upper by two split pins. (*Reproduced from Jones, p. 178, by permission of the Oxford University Press.*)

Figs. 5-A and 5-B: Haas's experiment beautifully illustrates Wolff's law. Fig 5-A shows the phalanx and the metacarpal reimplanted at the original site, and Fig. 5-B, the phalanx and the metacarpal transplanted into the muscles of the back. (The time after transplant is fifty-five days.) The reimplanted bones, which were subjected to the normal stimulation of function, show less evidence of degeneration than the transplanted bones removed from the normal stimulus. (*Reproduced from Haas, p. 427, by permission of Archives of Surgery.*)

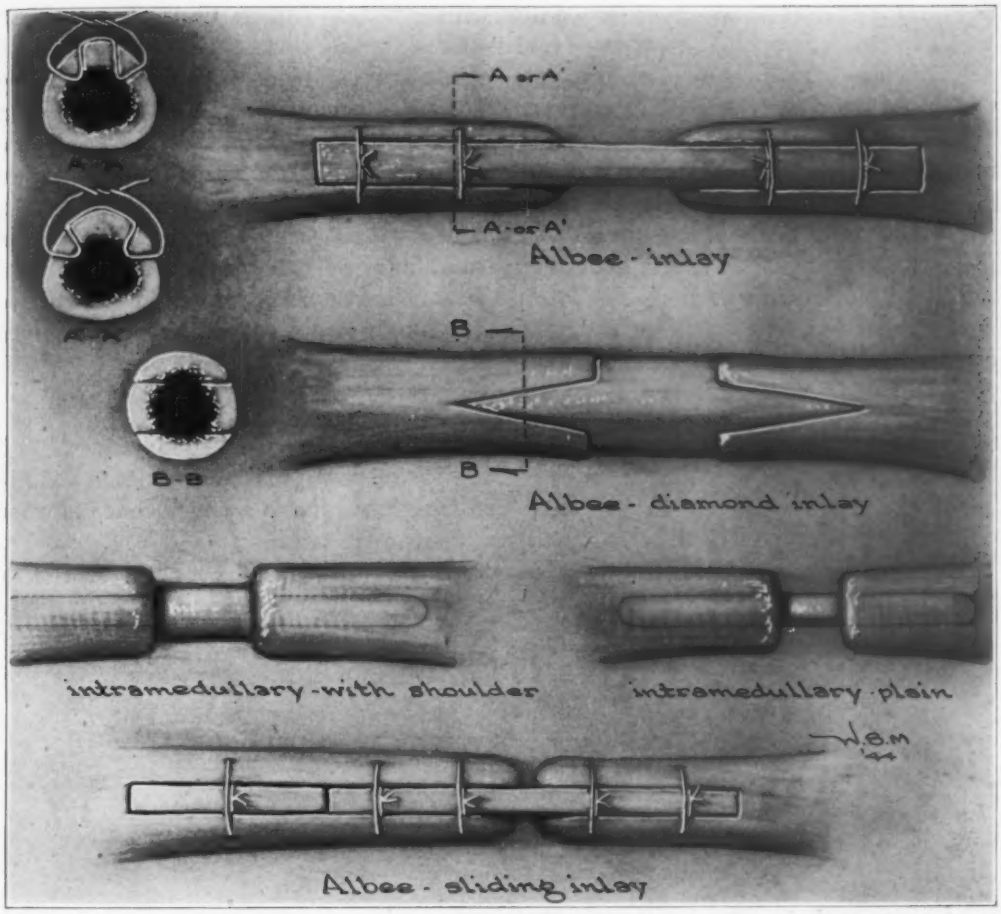

FIG. 6

living bone, if transplanted into bone, survives, provided function is demanded. Bone in soft tissue has only a fleeting existence. This was also confirmed by Haas, in 1922, and by McMaster, in 1937. Phemister, in 1914, added to our knowledge of this theory by showing that, in fragmented grafts, many pieces died. However, slow and scanty osteogenesis occurred about most of them. Free periosteum does not produce bone. MacWilliams, in 1941, showed conclusively that grafts transplanted with periosteum lived. His work is actually the basis for the osteoperiosteal graft. Dobrowolskaja, in 1916, reported on the cultivation of bone tissue *in vitro*. When whole pieces of bone, with periosteum and marrow attached, were employed, such luxuriant cell growth occurred, accompanied by intense round-cell infiltration, as to obscure the details of growth. When pieces of bone were cultivated without either periosteum or marrow, a definite and clear growth of bone cells, free from round-cell infiltration, occurred. On the other hand, cultivation of the periosteum produced hardly any growth. Spongy bone containing marrow tissue gave rise to active growth, in which round-cell infiltration predominated.

Hey Groves, in 1917, called attention again to the fact that the bone graft was both osteogenic and osteoconductive. He emphasized the importance of the autogenous graft, particularly the massive graft (half cylinder), and stressed the need of complete fixation. He further demonstrated that the employment of nails and screws, so useful in the complete fixation of the massive graft, did not interfere with osteogenesis.

Thus ends, to a large extent, the experimental era upon which the present knowledge of bone-grafting is based. Experimental work at the present time is devoted largely to

variation in technique and theory concerning osteogenesis. Among the recent contributions along this line, which are notable and valuable, is the work of Venable, Stuck, and Beach. These writers demonstrate the value of the inert metals in graft fixation. Alloys in which the constituent metals are adjacent in the electromotive series (slight difference in potential) do not cause electrolysis. Stainless steel and vitallium, which is made up of cobalt, chromium, and nickel, are the two materials most commonly used for screws, pins, nails, cups, *et cetera*. Probably the leading controversial subject affording much experimental interest at this time, hinges, strangely enough, about the origin of bone. Two schools of thought persist. One believes in the cellular or osteoblastic theory, and the other in the biochemical origin. The latter contends that bone is formed in the embryological connective tissue on a biochemical basis. The problem yet remains to be solved. Present-day thought seems to embody both processes.

Clinical Contributions to Bone-Grafting

Albee,[2] in 1919; Jones, in 1921; Kirk, in 1924; Henderson, in 1936; Campbell, in 1939; and others, reported a large series of bone-graft operations for non-union with remarkably high success. A review of these contributions reveals a concurrence of views relative to the fundamentals of bone-grafting. They are as follows:

1. There is a preference for the autogenous graft. Orrel, in 1937, advocated the use of *os purum*, *os novum*, and boiled bone in small bone defects, but he preferred the auto-

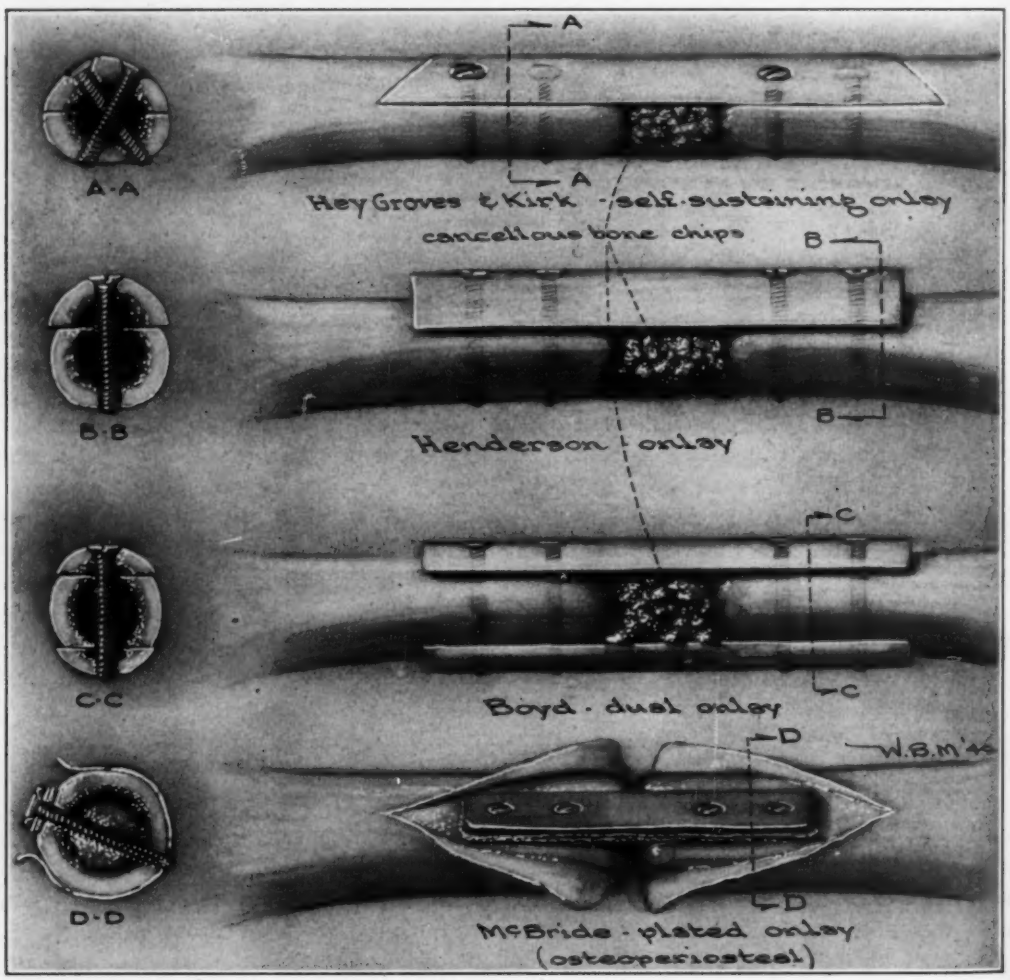

FIG. 7

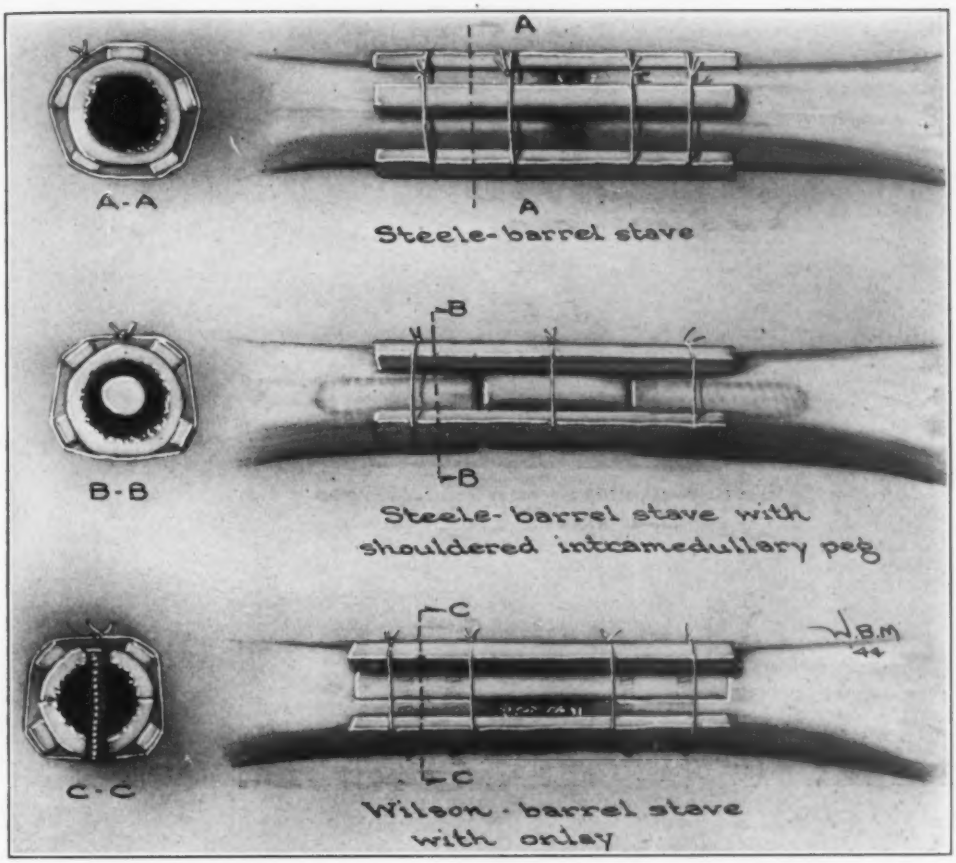

FIG. 8

genous graft in bridging large bone defects. It is the consensus that the heterogenous graft rarely becomes a part of the host.

2. The massive onlay or inlay is the preferred type of graft.

3. Vitallium or stainless-steel screws are preferred for internal fixation; and plaster-of-Paris is preferred for external fixation, the joints above and below being included.

4. The graft should be at least three times the length of the defect, when possible.

5. The period of fixation should be three to six months for the lower extremities, and six to twelve weeks for the upper extremities.

6. A brace should be employed on the lower extremity for three to six months, and should be accompanied by physiotherapy.

It is obvious that these fundamentals are based primarily on the principles discussed in the historical section.

Kirk was among the first to report a large series of bone grafts for massive defects resulting from compound wounds. In 129 cases, bone defects were treated by bone-grafting; fifty-three were unsuccessful. The reasons for failure included infection and inadequate internal and external fixation of the graft. Other authors contributed smaller series. In order to bring our clinical knowledge in the use of the bone graft up to the present moment, the writer sent out a questionnaire to members of The American Academy of Orthopaedic Surgeons, inquiring as to the number of bone grafts performed for massive defects, type of graft, method of internal and external fixation, and a record as to success or failure. Eighty-eight members reported 548 bone-graft operations. An analysis of the replies revealed the following:

1. The autogenous graft is the universal choice.

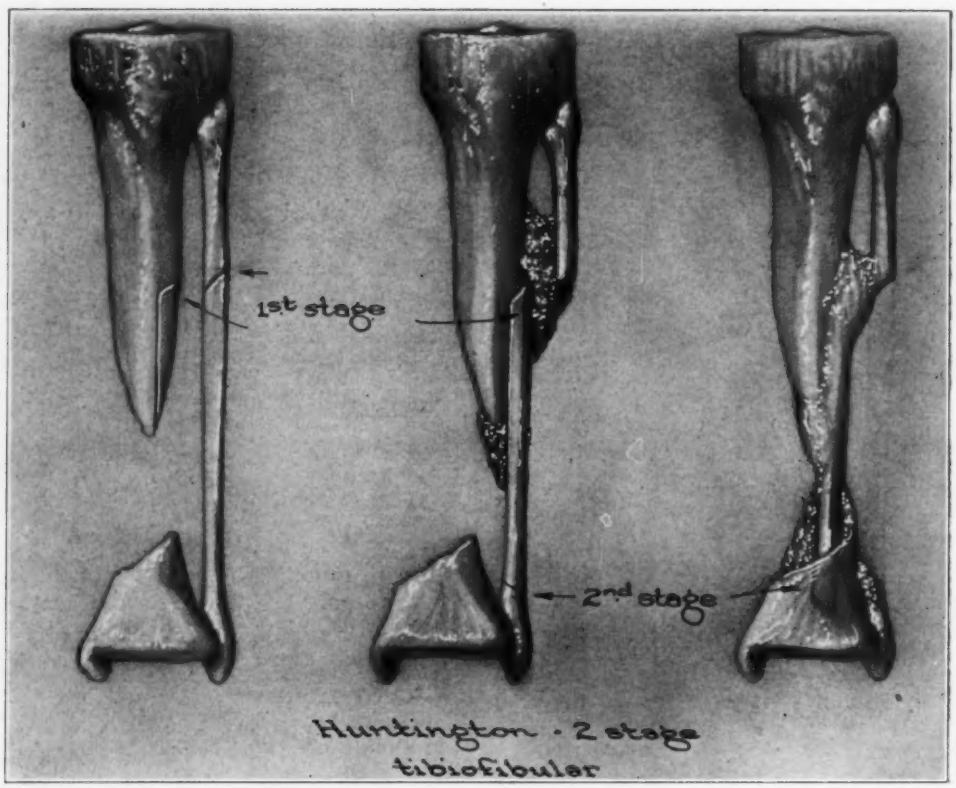
1st stage
2nd stage
Huntington · 2 stage
tibiofibular

FIG. 9

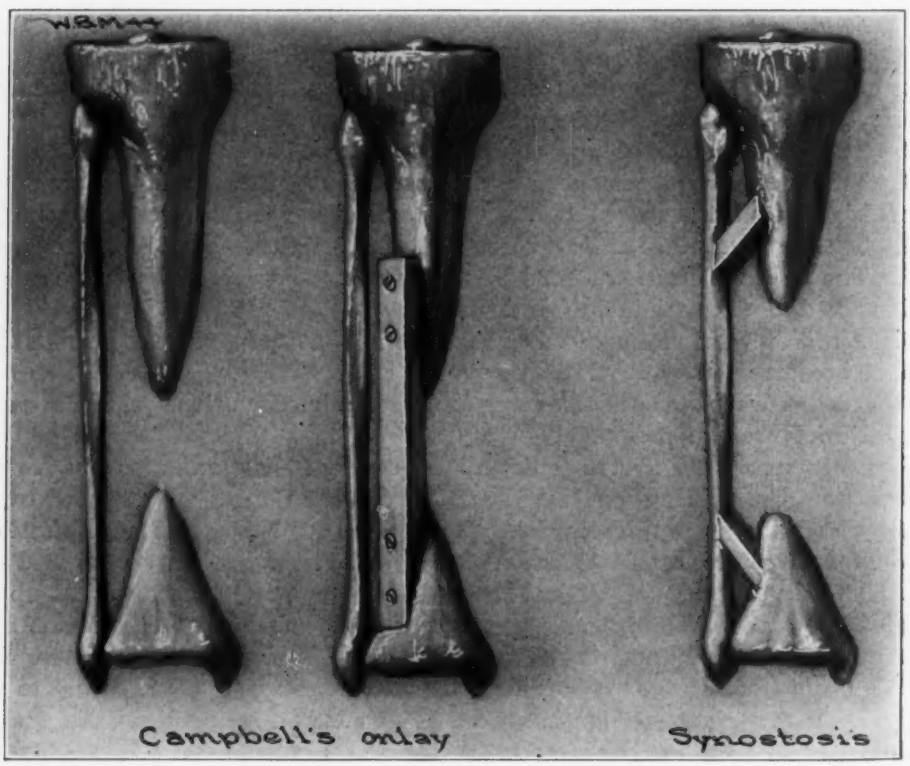
Campbell's onlay
Synostosis

FIG. 10

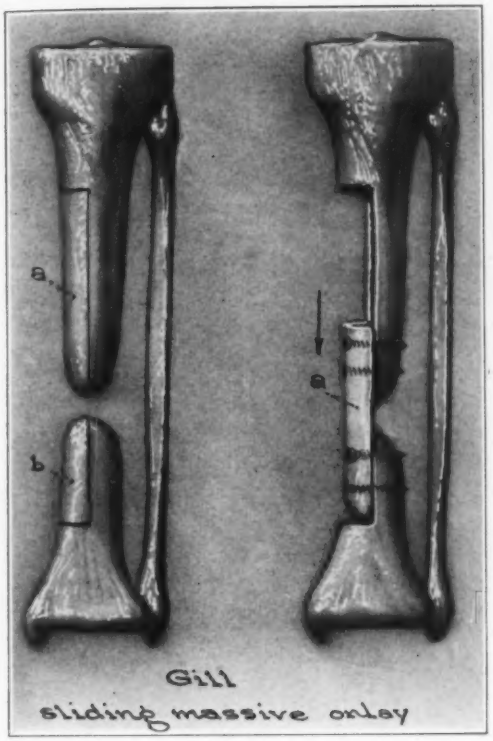

FIG. 11

FIG. 12

FIG. 13-A

FIG. 13-B

FIG. 13-C

Roentgenograms showing the loss of substance and bone atrophy, and the result three and a half months after bone-grafting. (*Reproduced from Kirk, The Journal of Bone and Joint Surgery, p. 771.*[22])

Roentgenogram shows excellent bony union twenty months after operation. (*Reproduced from Kirk, The Journal of Bone and Joint Surgery, p. 772.*[22])

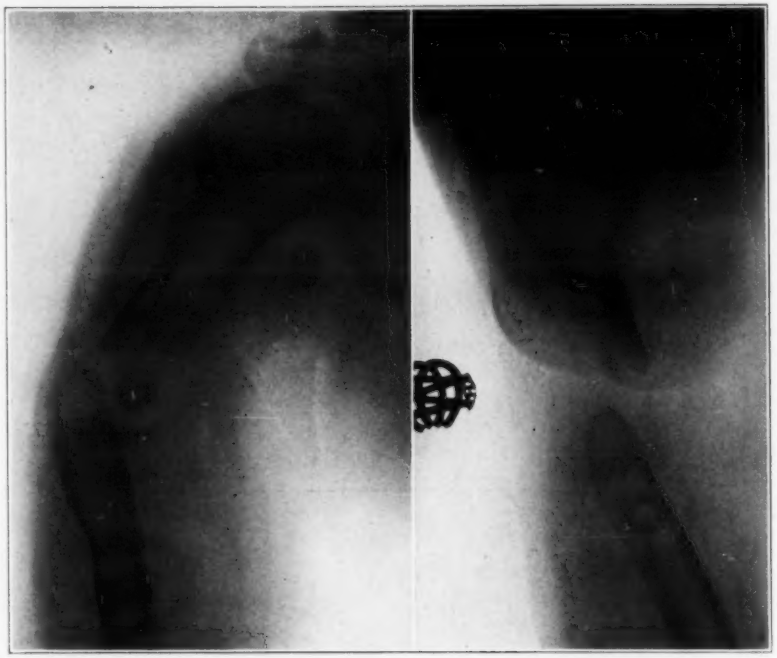

FIG. 14-A

Fig. 14-A: A large defect is illustrated in the upper third of the humerus, which followed a compound fracture with sequestration. (*Reproduced from Boyd, The Journal of Bone and Joint Surgery, p. 538.*)

Fig. 14-B: Appearance of the bone six weeks following application of a dual bone graft. This illustrates the clamplike action of the dual graft, and its holding power on the osteoporotic proximal fragment. (*Reproduced from Boyd, The Journal of Bone and Joint Surgery, p. 539.*)

Fig. 14-C: Appearance of the bone seventeen months after operation. Solid bony union has occurred despite postoperative infection. (*Reproduced from Boyd, The Journal of Bone and Joint Surgery, p. 539.*)

FIG. 14-B

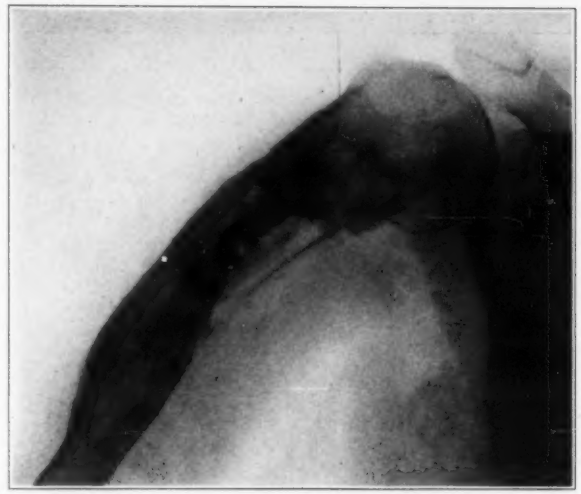

FIG. 14-C

FIG. 15-A

Non-union of the humerus of eleven months' duration, following compound comminuted fracture with infection and loss of bone substance. (*Reproduced from Boyd, The Journal of Bone and Joint Surgery, p. 547.*)

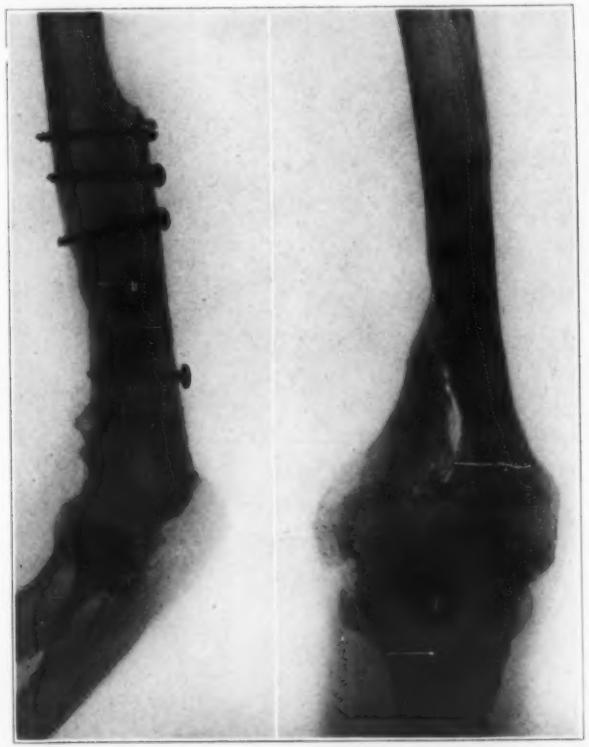

FIG. 15-B

Solid bony union is illustrated one year and eight months following onlay fibular graft in which vitallium screws were used. (*Reproduced from Boyd, The Journal of Bone and Joint Surgery, p. 548.*)

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FIG. 16-A

FIG. 16-B

Old gunshot wound with loss of substance and marked bone atrophy. A massive-type tibial graft was inserted into the proximal fragment after removal of the terminal thin cortical shell. The periosteum was first removed from that part of the graft so introduced. The lower end of the graft was fitted into a slot and a pocket which were chiseled into the distal fragment. Thus the graft was made self-retaining. A body plaster cast was applied several days before operation. (*Reproduced from Kirk, The Journal of Bone and Joint Surgery, p. 623.*[24])

2. The preferable graft is the massive onlay or the massive inlay; variations included the barrel graft by Steele, the dual onlay of Boyd, the tibiofibular synostosis, the two-stage fibular transplant (Huntington), and the plated osteoperiosteal graft (McBride). The addition of cancellous bone chips and the retention of the periosteum when possible, is strongly advised.

3. Almost universal preference was shown for the stainless-steel or vitallium screw for internal fixation. The self-sustaining graft is strongly urged by Kirk, Albee, and others. Plaster fixation is the common choice for external fixation.

4. Thirteen failures were reported in the entire series.

Miscellaneous but instructive comments are as follows: Amputation should be given first consideration, if the scar defect cannot be adequately repaired or if infection is irremediable. Bone continuity in the upper extremity is to be preserved at all cost. Approximation of bone fragments, regardless of the shortening ensuing, is advocated by two contributors. Fixation after bone-grafting is extremely important. The weak period of the graft is during the eighth to the tenth weeks. One contributor thinks that bridging defects of more than two and a half inches "was not worth all the surgery and risk involved".

CONCLUSIONS

The bridging of large bone defects in compound wounds is practicable, and has for its basis the monumental experimental work of contributors for the past several centuries, as well as the large clinical applications and contributions during the past two or three decades. Massive autogenous bone grafts, perfectly fitted to the host and held by adequate internal and external fixation, confirm our present and past theories of osteogenesis, and behave according to the laws of Roux and Wolff. One stumbling block has been mechanical fixation, and this has been circumvented by the massive graft with internal and external fixation. The elimination of infection through the systemic use of sulfonamides and the local and systemic use of penicillin, the replacement of skin and scar defects, and the restoration of the normal physiology, all of which might be considered as converting the compound fracture into a simple fracture, seem to have a brilliant future in the handling of this most difficult of all fracture complications.

The writer wishes to take this opportunity to thank the various members of The American Academy of Orthopaedic Surgeons for their generosity in time and effort, as evidenced by the responses to the questionnaire, upon which this study is in part based.

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DISCUSSION

Dr. Paul B. Magnuson, Chicago, Illinois: These papers have been wonderfully instructive, definite, concise, and to the point. They have all stressed principles, with very little emphasis on particular methods. Dr. Murray and Captain Mech laid particular stress on treatment of the patient first and treatment of the fracture afterward. This is putting the horse where it ought to be, in front of the cart. An ununited fracture is never an emergency. The patient who has the ununited fracture is of primary importance. The method to be used cannot be advised or planned until the patient is in condition to accept the operation, from the physical, nervous, and mental standpoints. Certainly the preparation of the fracture for bone surgery must be carefully worked out, not only from the standpoint of the patient's physical condition, but from the standpoint of local conditions such as infection, scar tissue, skin coverage, and circulation, to say nothing about the muscles and joints above and below the fracture. Preparation of the tissues, before bone repair is attempted, cannot be too strongly emphasized. Dr. Brown has beautifully shown how he is doing it now.

When I was asked to discuss this paper, I went back over my experience with the transplantation of bone into large defects, and I find the first one was done thirty years ago. The entire lower two-thirds of a radius was replaced by a tibial graft, with one end set into the upper third of the radius and the other end of the graft pressing against the carpal bone. I was told at the time, by older and wiser heads, that it could not be done. However, it was done, and done on the principle that a graft held firmly and well fitted into the host bone, even though attached only to one fragment, will grow, if it is put to work. Bone, like brains and muscles, develops better with use and exercise, and, it seems to me, that the essential thing in any graft is to set it in in such a way that it will immediately bear strain in a longitudinal direction. It should be set in so firmly that there will be no twist or torque, and the graft will not move on the host bone to break up the circulation as it penetrates the graft. This firm fixation at each end, to me, is the most important thing to accomplish in applying or inserting a graft. How it is to be done is a question that must be figured out at the time of surgery in each case individually. The principles of immediate weight-bearing and firm fixation are the two things to be held constantly in mind.

Four other cases of bridging large defects illustrate this principle. In the first, bone was replaced in the lower third of the femur by two long grafts, after resection of the lower femur for Ewing's tumor. In this case the grafts were set in like an inverted pyramid. The point of the pyramid was driven into the upper end of the tibia, so that the grafts were held firmly by cancellous bone, but with no other fixation; the base of the pyramid met the host bone, the lower end of the upper fragment of the femur, on the sides, and was mortised to maintain weight. Marked stretch was put on the soft tissues between the lower end of the femur and the upper end of the tibia, and the upper end of the graft was pressed against the lower end of the femur, mortised in and fastened firmly with stainless-steel screws. This procedure put these grafts to work immediately, holding the lower end of the femur and the upper end of the tibia apart.

The next case was that of a child who had a tremendous deformity of the radius in the lower third. The fragments of the radius were angulated so much that the points of the fragments could be seen protruding beyond the ulna laterally. The bone was soft, and three previous bone grafts had been inserted, none of which had held. Needless to say, the radius was tremendously shortened, and the bone was so soft it was impossible to reduce the deformity while the operation was being done. We, therefore, inserted Kirschner wire in each fragment of the radius, and put on traction in opposite directions for about two weeks, until the radio-ulnar joint was re-established in normal relation at the wrist and the ends of the ununited fragments were pulled into alignment. It was only after this deformity had been reduced and the muscles had been properly stretched that the operation was attempted. The bones were so soft that it was very difficult to

fasten them securely without a graft. One graft was inserted between the ends of the fragments, with another graft overlying as an onlay. The two grafts were screwed together, and the onlay graft was fastened to the upper and lower fragments; this gave immediate stability. The ends of the graft had to be held by wires, because near the wrist the bone was so soft a screw would not hold. Also, the bones were so small that any screw would destroy too much of the diameter and thus weaken them further.

The next case was in an older individual, who had almost the same type of deformity, with great decalcification of bone. This was repaired in much the same way, after the deformity had been reduced by traction and countertraction by Kirschner wire.

The last case was much like the first, except that it involved the lower end of the humerus, one third of which had been lost as the result of a compound fracture. In this case, a long graft was taken from the tibia, and one end was shaped a little like the lower end of the humerus. As we could fasten the graft at only one end, the upper fragment of the humerus was split and the shaped end of the graft was forced into contact with the humerus. The muscles of the upper arm were forced into full extension, and the graft was then clamped into the split upper fragment, and was fastened with two ivory screws which transfixed the fragment and the graft. The triceps muscle was attached to the upper end of the ulna. Instead of placing a cast on the patient, we put him in a splint with a hinge at the elbow and started motion within the first week. The fibrous tissue which covered the upper end of the ulna acted as a good covering for the lower end of the graft, and gave good support; in this case the heavy fibrous tissue was not removed from the upper end of the bones of the forearm. The arm was never immobilized, yet the graft was so firmly clamped between the two halves of the upper fragment that there was perfect fixation between the graft and the host bone, even though we established motion at the elbow immediately. There was complete bony union, with 105 degrees of motion. The patient has practically normal motion at the elbow joint and good muscle control; the joint is painless.

These four cases seem to me to illustrate three principles: immediate establishment of weight-bearing in part or all of the graft; complete firm and permanent immobility between the graft and the host bone; fixation with whatever material works best. In these four cases, wire, stainless-steel screws, and ivory screws were used in different cases. They worked equally well, because the fragments were properly supported, and were put in so that mechanically the graft was put to work immediately and did not move under any conditions.

DR. D. B. PHEMISTER, CHICAGO, ILLINOIS: There are many interesting problems in this symposium, but in order to try to make a point which I have attempted before with little success, I shall confine my remarks to one subject. It is the use of the heavy onlay bone graft without screw or tie fixation in the treatment of ununited fractures, in which the fragments are so well approximated that they do not require reduction. An incision is made, and the periosteum is reflected from the fragment ends on one side. A heavy bone graft is inserted into the gap, and the soft parts are sutured snugly about it. The limb is immobilized in a cast for two to three months.

In ununited fractures that have never been infected, the operation is simple, is quickly performed, rarely becomes infected, and leads to bony union in a high percentage of cases. The graft becomes united to the fragments above and below the fracture site, after which the callus in the fracture line soon ossifies. In some cases, the callus has been curetted from the fracture line on the exposed side, while, in others, it has not been touched, and the results have been equally satisfactory. The following cases are examples of numerous successes that have been obtained by this method.

An ununited fracture of the mandible was treated by the application of a graft from the ilium to the medial side of the fragments through an inferior incision, the wound was tightly sutured, and the upper and lower teeth were wired together. Union occurred promptly, and a roentgenogram, taken four months later, showed the intermediary callus well ossified.

A fracture of the ulna was treated by curettement of a part of the exposed intermediary callus and the application of a long onlay graft from the tibia through a posterior incision. A roentgenogram, taken twelve weeks later, showed solid union of the fracture.

An ununited fracture of the upper third of the femur of two years' duration was treated by the application, through a lateral incision, of two whole-thickness tibial grafts to the denuded lateral surface of the fragment ends; these were held in place by suturing the soft parts. Roentgenograms, taken three months later, showed that the grafts were already united to the fragment ends, and that the intermediary callus was considerably ossified. Walking was resumed after four months, and a roentgenogram, taken at seven months, showed the intermediary callus to be completely ossified.

A fracture of the lower third of the tibia had been treated originally by the application of a metal plate and screws, with resultant non-union. When seen at the end of a year, the metal had been removed, leaving the fragments in good alignment. A heavy onlay graft was applied through a posteromedial incision, leaving the intermediary callus undisturbed. Bony union followed rapidly, and roentgenograms, taken five months after operation, showed the intermediary callus to be ossified.

In carefully selected cases of long-standing, compound fracture, with infection limited to one side of the bone, and non-union, such a graft may be inserted into a clean field through an incision on the opposite side, without disturbance of the intermediary callus, and healing may be obtained without the occurrence of infection. This is illustrated by two cases of fracture of the tibia, where localized infection of the compound

anterior portion is frequently seen. In one case, the graft was applied to the posterior side through a posteromedial incision two months after the anterior wound had healed, and in the other, a small granulating wound was still present anteriorly, when the graft was applied posteriorly. In each case there was healing *per primam*, and rapid union of the fracture. By the discriminate use of this procedure, some patients may be operated upon months or even a year before it would be safe to perform the usual operation of cutting through the old infected field.

Anyone who has doubts that a fibrous intermediary callus will undergo metaplasia into bone, following the union of a heavy onlay graft to the fragment ends, will have them removed if he tries this procedure.

DR. W. E. GALLIE, TORONTO, ONTARIO, CANADA: I feel sure we all agree that one of the great advances in the surgery of our time has been the introduction of bone-grafting. Anything I have to say, therefore, must not be interpreted as indicating that I have any objection to this great type of surgery. There are two or three points, however, which should be added in order that this symposium may be more complete.

You will recall that the participants in the symposium concentrated on the technique of bone-grafting to overcome non-union, and on ways of overcoming the tendency for ununited fractures, which had been septic, to flare up with infection after bone-grafting operations. It would be well if we remembered, in this regard, that there are other ways of obtaining union of septic fractures, without recourse to the preliminary grafting of skin, as described so well by Dr. Brown, and to the transplantation of bone. You will all remember that, in the last War, Dr. Winnett Orr introduced certain principles that have been of the utmost value in the treatment of osteomyelitis and of compound fractures. Among other things, he suggested that patients who had septic ununited fractures should be operated upon, for the purpose of overcoming the non-union, while the wound was still discharging, three or four months after the wounding. He taught that such wounds might be safely opened up, so as to allow sequestra to be cleared out, the ends of the fragments freshened, and the bones brought together in good alignment. The wound was left wide open for drainage, and the limb was encased in plaster. As a result of such treatment, 75 per cent. of the septic non-unions go on to union. As an actual fact, the process of consolidation is often speeded up, because of the rapid callus formation that occurs in mildly septic wounds.

Another point I would make is that some of these patients, with septic ununited fractures, might be better treated by amputation than by repeated efforts to overcome sepsis and to induce union. Over and over again, I have seen men wounded in the last War readmitted to hospital, with recurrences of osteomyelitis, and, on too many occasions, have seen them succumb to septicaemia. I cannot help thinking that an amputation might have given them happier and longer lives. I have to suggest, therefore, that, while the first object of the surgeon should be to get a good union and to save the limb, in cases of chronic osteomyelitis associated with non-union, he should consider whether or not an amputation might not be the wiser course.

MAJOR GENERAL NORMAN T. KIRK, WASHINGTON, D. C.: I think these papers are wonderful, and I am glad to have heard them. As Dr. Magnuson and Dr. Murray have pointed out, I do not think we have to have a laboratory for the clinician to know when the patient is ready for surgery. It is important to give blood transfusions. Blood plasma costs $10.00 a pint, and it takes $6.00 a day for hospitalization.

I am delighted to hear what the plastic surgeons are doing to help the orthopaedic surgeons. I am distressed to hear what Dr. Phemister recommended to these young men. That is what I try to have them not do. I know we have to get the scars out before we do bone work, or the circulation of the bone graft is impaired. I want to make a plea that all scar tissue be removed, before any surgical procedure is done. I was a bit disappointed in the statement made by Captain Mech, relative to partial suture of wounds. Wounds have become infected because they were tightly closed, and caused loss of soldiers' lives. Do not close a wound. After the last War, I saw an excellent surgeon in orthopaedics go through the ward, read the history, and, if, after six weeks, a wound had not healed and had a sinus, he would order that it be scraped a little more and tightly sutured. In six weeks the man still had a sinus. Leave the primary wounds open, whether in war or at home. In this country recently, Colonel Peterson found three amputations from gas gangrene, because surgeons "took a chance" on débridement and tight suturing of the wound. The doctor did not "take a chance"; it was the patient who took the chance.

DR. J. ALBERT KEY, ST. LOUIS, MISSOURI: I am sorry General Kirk has left, because five years ago I felt just the way he does. During the past five years I have been using the Phemister graft or free graft, and I have had more success with that simple procedure than with former elaborate methods of grafting. It has three advantages: First, the graft does not need to be long, and can nearly always be removed from the tibia of the injured leg. This eliminates temporary disability and possible fracture of the sound leg. Second, it can be placed close to the ankle or knee joint where there is a short fragment. Third, the operation is not difficult. I feel that that graft should be used in the Army. It is indicated only where the fragments are in satisfactory position and are fixed by fibrous tissue. It can be combined with multiple drilling or a metal plate. In old, previously infected fractures, it is not necessary to excise the scar tissue. I do not advise any graft or bone-drilling in the presence of active infection.

(*Continued on page 596*)

END RESULTS OF TREATMENT OF FRESH FRACTURES BY THE USE OF THE STADER APPARATUS*†

BY C. M. SHAAR,
Captain, Medical Corps, United States Navy

FRANK P. KREUZ, JR.,
Commander, Medical Corps, United States Navy

AND DONALD T. JONES,
Lieutenant Commander, Medical Corps, United States Naval Reserve

External skeletal fixation is not the ideal treatment of fractures to the exclusion of all other methods. Of the various means of application of the principle of external fixation, the authors prefer the Stader reduction and fixation splint. Correct technique and meticulous attention to detail will give satisfactory results; faulty technique may result in failure.

This method of treatment has already been described by the authors. The Stader splint affords rigid fixation, allows the patient to become ambulatory in days instead of months, facilitates transportation, requires a minimum amount of nursing care, is reasonably comfortable, and permits immediate active motion without fixation of the adjacent joints.

In 110 consecutive cases of acute fractures treated at the Naval Hospital, Philadelphia, 107 were returned to duty, or resumed previous occupation. Two of these fractures resulted in non-union,—one in the femur and the other in the tibia. Bone grafts were later used, and both patients made uneventful recoveries. One patient was invalided from the Service (surveyed). This case was that of an extensive compound comminuted fracture of the left ankle, with multiple fractures of the spine.

This group of patients consisted of service men of the Navy and Marine Corps, veterans of the first World War, and Navy-Yard workers coming under the Civil-Service Act. Their ages varied from eighteen to sixty-seven years. This group is similar to a cross section of those treated in civilian hospitals.

Femur: Eleven fractures of the femur were treated by this method,—nine simple fractures and two compound. Six cases were treated by the Stader splint alone with an average period of immobilization of ten weeks. Four cases were treated by fixation in the splint for an average of eight weeks, followed by cast fixation for five weeks. The average period of total immobilization was thirteen weeks. One non-union resulted from a transverse fracture of the middle third of the shaft, which had been treated by immobilization in the splint and then in a cast. It is felt that too forcible apposition was the cause of the non-union, as postreduction roentgenograms showed no distraction; however, progressive bone absorption at the fracture site developed. A bone graft was successfully used. The youngest patient in this group was twenty-three years and the oldest, sixty-two years.

Tibia and Fibula: Of forty-four cases of fractures of the tibia and fibula, two cases were simple fractures of the tibia, and forty-two cases were fractures of tibia and fibula, six of which were compound. There were no fractures of the fibula alone treated by this method of fixation. The two cases of tibial fractures were treated by the Stader splint alone with average period of immobilization of eleven weeks and average period of total disability of sixteen weeks. Seventeen cases of fractures of tibia and fibula were treated with average total immobilization of eleven weeks and average period of disability of eighteen

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† The opinions or assertions contained herein are the private ones of the writers and are not to be construed as official, or reflecting the views of the Navy Department or the naval service at large.

weeks. Of the remaining twenty-five cases, nineteen were simple fractures of the tibia and fibula treated with average period of immobilization by Stader splint of eleven weeks and by cast with average period of eight and one-tenth weeks. Of the six cases of compound fractures, five cases were treated with average period of immobilization by splint of eleven weeks and immobilization by cast with average period of immobilization of nine weeks. One non-union developed in a case of multiple compound fractures of the tibia with associated tibiofibular separation (distal) and fracture of the internal malleolus. Of these twenty-five cases, the average period of total disability was twenty-eight weeks with an average total disability of all the fractures of the tibia and fibula of twenty-four weeks.

Os Calcis: The fourteen cases of fracture of the os calcis were all simple fractures. Twelve were immobilized in a Stader splint for six weeks. Two cases were treated with a combined splint and cast for six weeks; one of these was immobilized in a cast for an additional four weeks, and the other for an additional five weeks. These two cases were badly comminuted fractures where it was necessary to control the forefoot and to aid in the restoration of the tuber-joint angle and correct abduction of the forefoot caused by calcaneocuboid subluxation. The youngest patient in the group was nineteen years old and the oldest, fifty-four.

Humerus: There were seven simple fractures and three compound fractures of the humerus. Six cases were treated by the Stader splint for an average period of nine and two-tenths weeks. Four cases were treated with the Stader splint for eight weeks and then with a cast for four weeks. The average total period of immobilization was twelve weeks. The youngest patient in this group was eighteen years of age, and the oldest, forty-nine years.

Radius: There was one case treated by the Stader splint for six weeks, and seven treated with the Stader splint for six weeks and a cast for four weeks. The average total period of immobilization was ten weeks. The youngest patient in this group was eighteen years old, and the oldest was forty-seven.

Ulna: There were four simple fractures of the ulna, two of which were treated by the Stader splint for an average of seven weeks. The other two were treated by the Stader splint for an average of five weeks and further immobilized in a cast for three weeks. The average period of total immobilization was eight weeks. The ages of these patients ranged from twenty-five to forty-six years.

Radius and Ulna: There were eight simple fractures, one of which was treated with the Stader splint for twelve weeks. The seven other cases were treated with the Stader splint for seven weeks, and were further immobilized in a cast for six weeks. The average total immobilization was thirteen weeks. The youngest patient in this group was twenty years old, and the oldest was twenty-seven.

Clavicle: There was one simple fracture which was treated by immobilization in the Stader splint for six weeks. The age of this patient was twenty-one years.

COMPLICATIONS

Pin Seepage

We have had no infection from pins in 110 consecutive cases of acute fractures, except in one case in which an abscess developed at the tibial-pin site eight months after the patient had returned to duty. Roentgenographic examination did not disclose the presence of any osteomyelitis, and healing followed promptly after incision of the abscess. Pin seepage does not indicate actual infection, and the surgeon must differentiate between true infection and slight innocuous moisture at the pin site; the latter has been present in about 10 per cent. of our cases.

The causes of pin seepage include: movement of the skin about the pins, skin tension, loose pins, insertion of pins in the fracture hematoma, insertion of pins through traumatized or devitalized soft tissues, local irritating factors, thermal necrosis, and electroly-

TABLE I

SUMMARY OF 110 CONSECUTIVE ACUTE FRACTURES TREATED WITH THE STADER SPLINT AT THE NAVAL HOSPITAL IN PHILADELPHIA

Bone	Total No. of Cases	Average Period of Disability (*Weeks*)	Simple Fractures			Compound Fractures		
			No. of Cases	Immobilization by Splint (*Weeks*)	Immobilization by Cast (*Weeks*)	No. of Cases	Immobilization by Splint (*Weeks*)	Immobilization by Cast (*Weeks*)
Femur*	11	17	6 2	10 7	0 4	2	9	6
Tibia	2	16	2	11	0	0	0	0
Tibia and Fibula *	42	18 28	17 19	11 11	0 8.1	0 5	0 11	0 9
Os Calcis	14	16	12 1 1	6 6† 6†	0 4 5	0	0	0
Humerus	10	14	6 1	9.2 8	0 4	3	8	4
Radius	8	14	1 7	6 6	0 4	0	0	0
Ulna	4	10	2 2	7 5	0 3	0	0	0
Radius and Ulna	8	17	1 7	12 7	0 6	0	0	0
Mandible	10	9	3	6	0	7	6.9	0
Clavicle	1	7	1	6	0	0	0	0
Totals	110	18	91			17		

* All patients resumed regular duty or previous occupation except three. In one fracture of the femur and in one fracture of the tibia, non-union developed and the patients are still under treatment. One patient with an extensive compound comminuted fracture of the left tibia and with multiple fractures of the spine was invalided from the Service. Cases of non-union are considered as failures, and are not included in the immobilization period.

† Patient was immobilized in a combined splint and plaster cast during the first six weeks.

sis. Repeated manipulations in cases of delayed reductions is undoubtedly one of the most important causes of pin seepage. In those cases where it is necessary to place an undue amount of force at the pin sites to obtain reduction, secondary increase in pin seepage is always noted; however, this is usually transitory. Since we have discouraged early weight-bearing, a definite decrease in pin seepage has been noted.

Pin Sequestra

Pin sequestra are the result of faulty technique, and are caused by thermal necrosis following the use of the electric bone drill, or by permitting dull pins to rotate in the same area without bone penetration. A ring sequestrum developed in one case, and was excised surgically. In a second case, a small ring sequestrum discharged spontaneously;

and in a third, the sequestrum was gradually absorbed with no infection. All of these complications occurred at the site of the tibial-pin insertions. One must keep in mind the possibility of fracture through the site of ring sequestra in case of injury. While this has not occurred in any case of our series, it is natural to presume such a possibility could occur.

Non-Union and Delayed Union

Union has resulted in the cases of acute fractures that we have so far treated, with the exception of one fractured femur and one fractured tibia. The causative factor of non-union in these cases was felt to be too firm apposition at the fracture site, as definite absorption occurred, and roentgenograms showed no evidence of distraction after reduction. These cases were subsequently successfully grafted. It has been our impression that all transverse fractures have had delayed healing; this may be eliminated by the new adaptation of the splint by which physiological apposition may be obtained. Approximately 15 per cent. of our fractures of the tibia have been of the transverse type.

Bowing

A complication that has occurred in two of our cases is that of bowing after the removal of the splint, when roentgenographically and clinically the patient had firm union. This is probably due to the fact that the splint has maintained the reduction so rigidly that functional stimulation of the callus, consequent to the irritation of slight motion, was notably lacking. This complication will be eliminated by the use of the new splint which we will routinely use in the future in all transverse fractures.

The merit of external skeletal fixation as a method of treating fractures should be given more consideration than it has in the past. It is more important to determine the value of this method from the standpoint of anatomical and functional results than to determine what instrument one should use.

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THE USE OF THE HAYNES SKELETAL-FIXATION APPARATUS IN DEFINITIVE ORTHOPAEDIC SURGERY*

BY ROBERT W. JOHNSON, JR., M.D., AND JOHN LYFORD, III, M.D.,
BALTIMORE, MARYLAND

External skeletal fixation is an established and popular method of treating fractures, although it is still the subject of considerable discussion as to specific indications and contra-indications. It is, however, not in respect to fracture treatment that the use of external skeletal fixation is herein described and advocated. The authors have found one of the forms of skeletal-fixation apparatus (the Haynes splint) a great aid in several types of true reconstructive and strictly orthopaedic or child-straightening procedures. The authors have used the technique described by Haynes.[1]

The cases presented were all elective operations, performed at leisure in excellently staffed operating rooms where operative risks are reduced to a minimum. All cases required open operation to correct the deformity or check the disease. Hence the use of the skeletal-fixation apparatus did not introduce any appreciable hazard, and was simply a most helpful mode, first, of manipulating the bones, and, second, of fixing them accurately while the fragments were under visual control.

The cases are in two groups: (1) corrective osteotomies and bone grafts, and (2) excision of joints (knees) for fusion in tuberculosis. The operative procedure in both groups is essentially the same. Two or three of the Haynes screw-pins are placed in the bone, conveniently proximal and distal to the main operative area, before the bone is made into two movable fragments. The screws can usually be placed through stab wounds, though the operative incision may include the screw holes in the non-tuberculous cases. A sterilized pin-block unit is then attached to each set of screws, and sterile dressings are placed over the holes before proceeding with the main operation. The predetermined operation is carried out with little or no interference from the pins or pin-blocks. During this procedure one can often gain much help in controlling and correcting the position of the bone ends by employing the pin-block units as levers. In fact, one should plan to place the pins and pin-blocks so that they may be a guide to the correction desired, as in the case of bowing deformities of the femora. Only after the entire operative procedure has been completed, except for the wound closure, are the connecting bars put on and tightened. It is then possible to be satisfied by visual check that the position and alignment of the bone fragments are all that can be desired. A test is made of the security of the fixation, and the position of the bones are checked again before the closure of the wound. The bars interfere somewhat during the closure of the wound, but such closures are so simple when fixation is secure that the bother of tying knots at a disadvantage is easily acceptable. The dressings are small and simple, and are easily put on without fear, since the splint mechanism is already in position and firmly fixed. In tuberculous cases, the pinholes are placed far from the main field of operation, and are protected; and in the authors' cases have shown no contamination or infection. Experience has shown that the incidence of superficial infection and drainage about the pins is directly related to the frequency of dressings. A satisfactory technique, associated with an almost negligible incidence of such complications, is to apply about the sterile pins, when they are first inserted, sterile dressings soaked in alcoholic gentian-violet solution; and then to wrap the leg and sterile apparatus with sterile dry dressings. These dressings are left entirely undisturbed for as long as possible,—that is, until the operative wound must be dressed to

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remove the sutures. The wound is entirely healed in three to four weeks when certain suture materials are used. Thereafter, similar dressings are applied by meticulous aseptic technique, keeping the apparatus sterile, and are again left undisturbed for as long as possible. Local discomfort and the temperature of the patient are reliable indices of the condition of the local wounds. The apparatus can be left on unchanged for as long as eight to ten months, and the limb and patient are freed of any other bulky form of support.

DISCUSSION

1. Fixation of the bone fragments is secure, and the patient is comfortable. There were no complaints about the apparatus in any case.

2. Ambulation is early and easy; muscle tone and joint mobility are maintained even in cases with long bone-healing periods. Patients may alter their positions in bed without help; consequently less nursing care is required, and general supportive measures can be more easily carried out. The patient can be ambulatory as soon as the general condition permits, and this is a marked advantage in treating the lower extremities, where large plaster hip spicas would otherwise necessitate weeks of bed care. This increased ambulatory ability decreases the period of necessary hospitalization, an economic and personnel factor of importance.

3. After osteotomies and bone grafts in which the Haynes splint is used, pain and swelling are often more severe during the first seventy-two hours than when a cast is used, because of the lack of compression of the soft tissues by a cast; bleeding and oozing from the wound may be greater for the same reason.

4. Reduction is maintained at the optimum position the operator is able to secure under visual control of the bone fragments.

5. Pin fixation under ideal operative conditions does not seem to add any appreciable danger of infection to the operation, and these cases have not become contaminated.

6. Physiologically, the use of pins piercing the medullary cavity may interfere with central circulation and inhibit the central callus, but in general the circulation of the operative area is protected by lessening the operative trauma, by exact immobilization of the bone fragments, and by the absence of constrictive dressings; it is enhanced by the early and more nearly normal functional use of the extremity and associated joints.

7. It sounds much more simple to carry out this procedure than it is in actual fact; but, with practice, each succeeding operation tends to be more easily performed, and the authors feel that they can safely and unhesitatingly commend it in cases similar to these. They are sure it will have a wider and wider field of usefulness in definitive orthopaedic surgery.

CASE REPORTS

CASE 1. A. M., a white woman, twenty-one years old, had malunion of fractures of both femora.

Present Illness: In September 1941, the patient had suffered simple fractures of the lower third of both femora. Both fractures had been treated with Russell traction. The left femur had healed solidly, but with bowing. Delayed union in the right femur had been treated by open reduction and internal fixation in December 1941, and, again, by open reduction and plating in February 1942. Severe bowing of both legs followed.

Physical Examination: Her temperature was 98.6 degrees; pulse, 88; respiration, 22; and blood pressure, 118 systolic and 72 diastolic. There was marked lateral bowing of both femora in the lower thirds. Motion in the right knee was from 180 to 50 degrees, and the knee was stable. Motion in the left knee was from 190 to 70 degrees; and the knee was relaxed with moderate genu recurvatum. Both patellae were movable, and the quadriceps power was good.

Laboratory Findings: Hemoglobin was 100 per cent.; white blood count, 7,600; and the Wassermann test and urinalysis were negative.

Course: On April 9, 1943, corrective osteotomy of the left femur was performed; fixation was obtained with the Haynes apparatus. The postoperative course was uneventful, and the patient was up in a wheelchair after two weeks, and was on crutches without weight-bearing after four weeks.

On May 21, 1943, a corrective osteotomy of the right femur was performed, with fixation obtained by

a Haynes apparatus. The postoperative course was uneventful, and she was up in a wheelchair after two weeks, and was on crutches with the Haynes apparatus in both femora after six weeks.

On August 8, 1943, the Haynes apparatus was removed from the left femur which appeared to be solid clinically and roentgenographically. The intra-osseous portion of one screw was left in the bone, because it had broken off at the cortical margin during weight-bearing.

On September 9, 1943, the Haynes apparatus was removed from the right femur which appeared to be solid clinically and roentgenographically. Twelve days later, without weight-bearing, the right femur showed false motion and angulation at the site of the

FIG. 1-A

FIG. 1-B

FIG. 1-C

Case 1. Showing preoperative bowing of both legs following malunion of both femora.

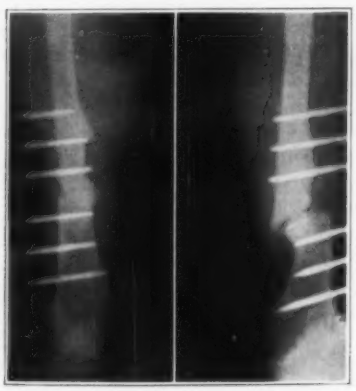

FIG. 1-D

FIG. 1-E

FIG. 1-F

Anteroposterior and lateral views, showing the bowing of both femora corrected following osteotomies. The bone fragments have been fixed with the Haynes external skeletal-fixation apparatus.

osteotomy. On October 8, 1943, open reduction was done on the fracture of the right femur, with a bone graft from the right ilium, and fixation with the Haynes apparatus. The screws were placed in the same holes in which they had been in the original osteotomy. The callus was seen to be typical of that of delayed union. The postoperative course was uneventful, except for secondary anaemia which responded well to blood transfusions. The patient was up in a wheelchair after three weeks, and was on crutches after four and one-half weeks. She was discharged bearing full weight on the left leg with the aid of crutches, and with the Haynes apparatus still in place on the right leg.

CASE 2. M. M., a white girl, fourteen years old, and a student, had a postpoliomyelitic genu recurvatum.

Present Illness: The patient had had a flaccid paralysis of both lower legs following poliomyelitis at the age of seven years. Subastragalar arthrodesis of the right foot had been done at eleven years. She walked well in braces until the genu recurvatum had progressed to the stage where braces could not adequately support the legs, and weight-bearing was impossible.

Physical Examination: The patient's temperature was 98.6 degrees; pulse, 86, and respiration, 20. The quadriceps were strong in both legs. Flaccid paralysis was present in both lower legs. There was marked bilateral genu recurvatum, and both knees were relaxed.

Laboratory Findings: Hemoglobin was 96 per cent.; white blood count, 5,750; and the Wassermann test and urinalysis were negative.

Course: On May 7, 1943, an osteotomy of the left tibia was performed with fixation with the Haynes apparatus. Her postoperative course was uneventful. The patient was up in a wheelchair after ten days.

On May 28, 1943, an osteotomy of the right tibia was done, with fixation with the Haynes apparatus. The postoperative course was uneventful. The patient was up in a wheelchair after two weeks, and went home on June 13, 1943. She returned August 12, 1943, when roentgenograms and a clinical check showed both osteotomies to be solidly healed and the genu recurvatum well corrected. She has been about freely with weight-bearing in braces since.

CASE 3. L. B., a white girl, fourteen years old, and a student, had a short right leg due to an old epiphysitis.

Present Illness: When four months old, she had had a swelling of the right knee, which had been incised; this had been followed by through-and-through drainage for one month and a cast for eighteen months. Thereafter, the right knee had been stiff, and the right leg had been shorter and smaller than the left.

Physical Examination: Her temperature was 98.6 degrees; pulse, 92; respiration, 20; and blood pressure, 108 systolic, and 68 diastolic. The patient walked on the right toes with the right knee flexed. Both tibiae were the same length, but the right femur was three inches shorter than the left, and was internally rotated. All muscles of the right leg were atrophied. The patella was small and freely movable. The intercondylar groove was deep, with the lateral condyle lying anteriorly. There was good quadriceps strength in the right leg. Motion in the right knee was from 165 to 45 degrees. Marked talipes equinus was present on the right, and the right tendo achillis was markedly shorter than the left.

Laboratory Findings: The hemoglobin was 86 per cent.; white blood count was 6,000; and the Wassermann test and urinalysis were negative.

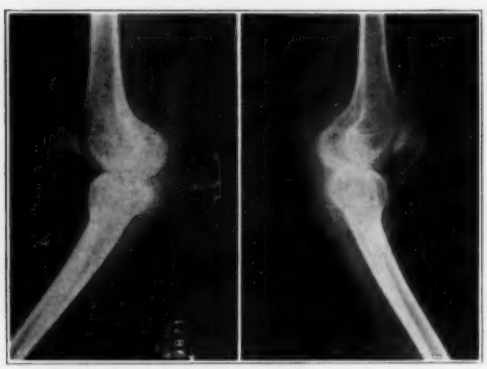

FIG. 2-A

Case 2. Lateral view of both knees with marked genua recurvata et valga after poliomyelitis.

Course: On June 25, 1943, the left femur was shortened two inches, with fixation in a Haynes apparatus. Her postoperative course was uneventful. The patient was up in a wheelchair two weeks after the operation.

On August 13, 1943, slight angulation of the left femur was corrected by loosening the Haynes apparatus, manipulating the femur, and tightening the Haynes apparatus.

On October 8, 1943, the right tendo achillis was lengthened. The patient walked with crutches without weight-bearing with the Haynes apparatus on her leg after five months.

On November 14, 1943, roentgenographic and clinical check showed the femur to be solidly healed; the Haynes apparatus was removed; and the patient was allowed to bear weight with the aid of crutches.

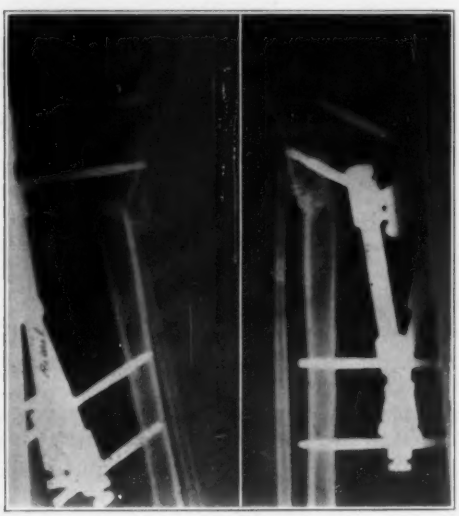

FIG. 2-B

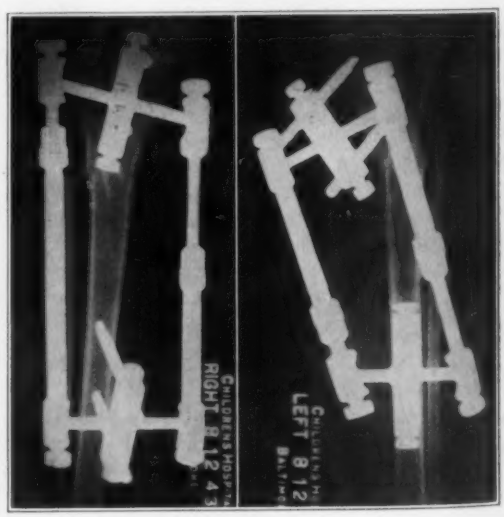

FIG. 2-C

Lateral and anteroposterior views of both knees after osteotomies.

FIG. 3-A

FIG. 3-B

FIG. 3-C

FIG. 3-A: Case 3. Preoperative photograph, showing shortening and flexion deformity of the right leg following epiphysitis.

FIGS. 3-B and 3-C: Lateral and anteroposterior views, showing the left femur after operative shortening of three inches.

CASE 4. W. P., a white boy, sixteen years old, and a student, had tuberculosis of the left knee.

Family History: His mother, grandfather, and two uncles had had tuberculosis.

Present Illness: The patient had had frequent contact with his mother who was hospitalized for tuberculosis. At the age of thirteen years, a fever had developed, which had persisted for six weeks and had been accompanied by pain and swelling of the left knee. He had been treated by bed rest for one month. Thereafter, the knee had swelled and pained on weight-bearing, but had been quiescent on rest. At fourteen years, he had had an inguinal adenopathy. There had been little change in the knee up to the time of examination.

Physical Examination: The patient's temperature was 98.2 degrees; pulse, 84; respiration, 20; and blood pressure, 112 systolic and 68 diastolic. There was slight, bilateral, inguinal adenopathy and several small, non-tender, movable nodules on the inner aspect of the right upper arm. The left knee was moderately swollen and cold. The patella was freely movable and slightly tender. There was motion from 180 to 100 degrees.

Laboratory Findings: Hemoglobin was 100 per cent.; white blood count, 8,600; and the Wassermann test and urinalysis were negative. Fluid from the left knee was sterile.

Course: On August 6, 1943, a biopsy of the left knee showed tuberculous granulation tissue.

FIG. 3-D

Lateral and anteroposterior views, showing the left femur well healed sixteen weeks after operation. The Haynes apparatus has been removed.

On August 19, 1943, the left knee was resected and fixed with a Haynes apparatus. The postoperative course was uneventful. The patient was discharged on the twenty-third postoperative day, with slight drainage from the wound; this finally healed well in six weeks. The patient was up and about on crutches without weight-bearing on the fourteenth postoperative day. After three months, light weight-bearing with crutches was permitted; the Haynes apparatus was still in place.

CASE 5. A. L., a white woman, aged twenty years, a nurse, had tuberculosis of the right knee.

Past History: The patient had had occasional blood-streaked sputum. She had lost twelve pounds in one year.

Present Illness: In March 1942, she had had an acute gastro-intestinal upset which had been followed

FIG. 4-A

FIG. 4-B

FIG. 4-C

Fig. 4-A: Case 4. Photograph showing the knee after resection for tuberculosis. The wound is well healed and the Haynes external skeletal-fixation apparatus is in place.

Figs. 4-B and 4-C: Lateral and anteroposterior views of the knee after resection for tuberculosis. (The illustrations have been reversed; it was the left knee that was affected.)

three days later by pain and swelling of the right knee. She had been treated with local heat, salicylates, and bed rest with traction for three months. The knee had then been stiff and painful. She had been treated with local heat and sulfanilamide and had finally been given a course of gold therapy for fourteen weeks.

Physical Examination: The patient's temperature was 99.4 degrees; pulse, 120; respiration, 24; and blood pressure, 130 systolic and 70 diastolic. The right knee was swollen, hot, and tender; there was some increased fluid; and the right patella was slightly limited in motion. Motion in the right knee was from 160 to 80 degrees.

Laboratory Findings: Hemoglobin was 75 per cent.; white blood count was 12,760; and the Wassermann test and urinalysis were negative. Fluid from the right knee was sterile.

Course: On May 31, 1943, a biopsy of the right knee revealed tuberculosis.

On June 17, 1943, the right knee was resected and fixed in the Haynes apparatus. The postoperative course was uneventful, except that the patient fell out of bed on the second postoperative night, but this accident did not affect the immobilization of the knee. The patient was up and about on crutches without weight-bearing after the fourteenth postoperative day, and was discharged on the thirty-first postoperative day with the wound well healed. After four months, light weight-bearing with crutches was permitted, with the Haynes apparatus still in place.

FIG. 5-A

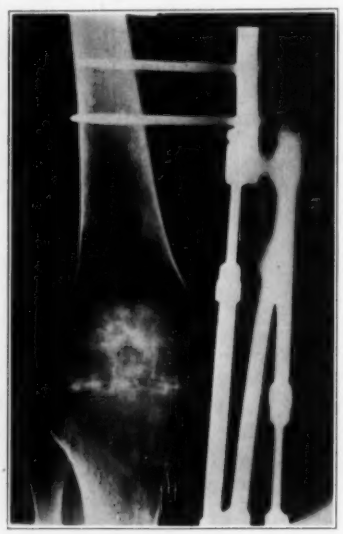

FIG. 5-B

Case 5. Lateral and anteroposterior views of the knee after resection for tuberculosis.

CASE 6. H. S., a white man, aged thirty-three years, a miner, had tuberculosis of the right knee.

Present Illness: At twenty-eight years, pain in the right knee and a tender mass in the popliteal space had developed; these had cleared up after several weeks. Thereafter, there had been constant pain and slight stiffness of the right knee, with gradually increasing swelling.

Physical Examination: The patient's temperature was 99 degrees; pulse, 78; respiration, 20; and blood pressure, 120

systolic and 78 diastolic. The lungs were clear to percussion and ausculation, except for diminished voice sounds over the posterior left upper lobe. The right knee was slightly red, slightly tender, and moderately swollen, and had motion from 140 to 50 degrees.

Laboratory Findings: Hemoglobin was 94 per cent.; white blood count was 9,600; and the Wassermann test and urinalysis were negative. Fluid from the right knee was positive for acid-fast organisms.

Course: On June 4, 1943, a biopsy of the right knee revealed tuberculosis.

On June 14, 1943, the right knee was resected and fixed with a Haynes apparatus. The postoperative course was uneventful except for the development of draining sinuses at each end of the incision, these finally healed after two months. The patient was walking on crutches without weight-bearing after three weeks, and was discharged after four weeks. Light weight-bearing with crutches and with the Haynes apparatus in place was allowed after four and one-half months. At six months, the roentgenographic and clinical examination revealed the knee to be solidly fused and the incision well healed; the Haynes apparatus was removed.

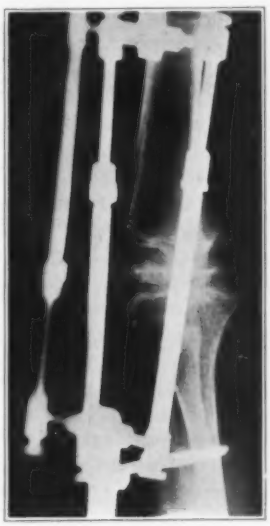

FIG. 6-A

FIG. 6-B

Case 6. Lateral and anteroposterior views of the knee after resection for tuberculosis.

The usual procedure with arthrodesis of the knee for tuberculosis was to allow the patient on crutches without weight-bearing in from fourteen to twenty-one days, and to allow partial weight-bearing at the end of three months.

1. HAYNES, H. H.: Treating Fractures by Skeletal Fixation of the Individual Bone. Southern Med. J., XXXII, 720, 1939.

Skeletal Fixation of Fractures. Am. J. Surg., LIX, 25, 1943.

DISCUSSION

DR. R. I. HARRIS, TORONTO, ONTARIO, CANADA: When I survey in retrospect the great advances in fracture treatment which have taken place in the past two decades, I am impressed by the great part which the use of transfixing pins and wires has contributed to these advances. The introduction of Kirschner wire, more than anything else, demonstrated what could be accomplished by force applied to the fracture fragments by means of a transfixing wire. It is true that methods of applying skeletal traction were in use before the introduction of Kirschner wire, notably the Steinmann pin; but the simplicity of Kirschner wire, the ease of its introduction, and the relative freedom from complications popularized this form of fracture treatment, and demonstrated how valuable a force it could be in the management of difficult fractures. Once the merit of transfixing wires was realized and the relative freedom from complications was appreciated, there developed a widespread use of skeletal traction for control of fracture fragments. Today every fracture clinic employs transfixing wires and pins in some form or other, and all are agreed that certain fractures can best be treated by transfixion methods,—for example, fractures of the os calcis and certain femoral and tibial fractures.

If we accept the merits of transfixing wires and pins for skeletal traction and accept the comparative innocuousness of the method, the extension of the principle to broader fields in fracture treatment is logical. The use of rigid pins instead of flexible wires, the use of pins in pairs or groups, the introduction of the pins through one skin surface only, the bridging of the projecting pin ends by some form of rigid bar, are successive steps by which modern forms of external pin fixation of fractures have been reached. The method is still in the process of development, especially in respect to the technical appliances for its application. In my belief, the principle of external pin fixation of fractures is sound, is at the beginning of its use, and is destined to become an important adjunct in fracture treatment.

I can recall myself as a junior medical student, listening to a tall and earnest speaker, expounding with almost fanatical zeal the doctrine that fractures should be treated by open operation, reduction under direct vision, and fixation with metal plates and screws. The speaker was Arbuthnot Lane, then a visitor to my country. His dicta upon fracture treatment were startling to my preceptors who hastened to point out to us that what we had heard was heresy and must not be practised except under the most exceptional circum-

stances. It is true that for a period Lane's principles proved difficult to apply, but today there cannot be one among us who does not agree that open reduction of fractures has been an important contribution to fracture treatment. It is my judgment that external pin fixation will prove a similarly valuable aid in fracture treatment.

External pin fixation has a field of usefulness in reconstructive surgery which may be even greater than its usefulness in fracture treatment. For twenty years I have been securing the tibia to the femur, after excision of the knee, by means of transfixing pins, introduced obliquely and in opposite directions through the tibia into the femur. I have come to regard this as an essential step in the operation. The availability of modern pin-fixation apparatus immensely broadens the field of usefulness of this principle in orthopaedic surgery. By use of such apparatus, it is possible to secure ununited fractures in the desired position before the bone graft is inserted, to ensure mobility of joints after bone-grafting, to simplify leg-lengthening, and to improve many forms of reconstructive procedures.

I have had opportunity to use the Stader, Haynes, and Roger Anderson forms of external skeletal fixation. Each has its merits and each has features which could be improved. These and all other forms of apparatus for external pin fixation of fractures are undergoing rapid improvement, and without doubt we shall have much improved apparatus within a short time. In my opinion, it would be wise for the manufacturers of such apparatus to pool their good ideas and patents, as I understand the manufacturers of artificial limbs are doing. Rigid adherence to patent rights is likely to freeze the types of instrument to the detriment of the principle and of the manufacturers themselves.

My experience with this method leads me to feel that it is singularly well adapted to certain fractures and is not so suitable for others. Fractures of all the long bones of the arm and leg are well treated by it, but certain fractures of these bones—for example, short fragments near joints, or multiple large fragments—are better treated by external skeletal traction than by any other means.

Infection is a complication to be feared, but the danger is much less than might be anticipated. In thirty-five cases, I have seen no serious infection and only one minor infection. Ring sequestra have given some trouble, but this formation is due to technical imperfections in the use of the apparatus and can be prevented.

THE USE OF UNTUBED PEDICLE GRAFTS IN THE REPAIR OF DEEP DEFECTS OF THE FOOT AND ANKLE

Technique and Results *

BY RALPH K. GHORMLEY, M.D., AND PAUL R. LIPSCOMB, M.D., ROCHESTER, MINNESOTA

From the Section on Orthopaedic Surgery, The Mayo Clinic, Rochester

Chronic ulcerative lesions or deep adherent scars of the lower extremities, especially of the foot and ankle, are often difficult to heal. If the lesion happens to be situated over a weight-bearing surface, over a bony prominence, or over one of the large tendons, the problem is likely to be even more difficult. Experience has shown that split-skin grafts and full-thickness grafts often fail to correct defects in these situations, especially if the ulcer or scar is deep. It then becomes necessary, not only to transfer skin to the defect, but also to replace the subcutaneous fat. It is a well-recognized fact that many ulcers do not heal because of ischaemia, due to scarring around the margins of the ulcer. Pedicle grafts readily supply blood to the margins and are often the only means of securing healing.

We wish to describe a surgical procedure in which untubed pedicle grafts are used in the repair of deep defects of the lower extremity, especially of the foot and ankle. This procedure was devised by one of us (R. K. G.) in conjunction with Dr. F. A. Figi, of the Section on Laryngology, Oral and Plastic Surgery of the Mayo Clinic. In this procedure, the graft is not tubed or shifted from one site to another; therefore, the time required to complete the procedure is appreciably less than that required in cases in which a pedicle graft is applied in the usual manner.

TECHNIQUE

First Stage: The proposed graft is outlined on the opposite calf or thigh. The graft usually is rectangular and may run in a longitudinal or diagonal direction. The distal end of the pedicle usually is transferred to the defect. In the beginning, care should be taken to make certain that this end of the graft eventually can be transferred to the defect on the opposite extremity, without producing kinks or tension of the pedicle. This can be done by cutting a piece of roller bandage or adhesive tape so that it will be the same size and shape as the proposed graft. One end of this pattern is anchored to the proximal end of the proposed graft and the other end is left free. By moving the free end of the pattern, one can determine whether the proposed graft can be transferred without producing kinking or tension.

An incision is then made along each of the long sides of the proposed graft. Each incision is made deeply enough to obtain a graft of the desired thickness. The two incisions are united by undermining the skin and subcutaneous tissues of the proposed graft (Fig. 1). Bleeding is controlled and powdered sulfathiazole or sulfanilamide is placed beneath the raised flap. (As this type of chemotherapy is used in each stage of the procedure, it will not be mentioned as the subsequent stages are described.) Then the incisions are closed with interrupted sutures of zytor or silk, which extend through the entire thickness of the flap. A Penrose drain is placed beneath the center portion of the flap and a pressure dressing is applied. The drain is removed at the end of forty-eight or seventy-two hours and another pressure dressing is applied. After the completion of this stage of the procedure, the patients are permitted to be up and about, and in many cases they are permitted to leave the Hospital. General anaesthesia for this stage of the

* Presented before the Annual Meeting of The American Academy of Orthopaedic Surgeons, Chicago, Illinois, January 26, 1944.

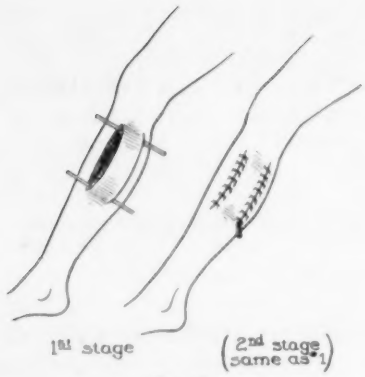

FIG. 1

First and second stages of the operation. A flap is elevated and then sutured in its original position. The first and second stages of the operation are identical.

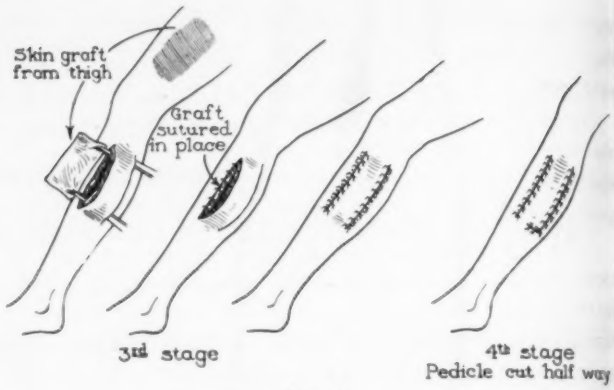

FIG. 2

Third and fourth stages of the operation. In the third stage, a split graft is sutured under the flap, and the flap is sutured in its original position. In the fourth stage, the distal end of the flap is cut halfway across and then is sutured.

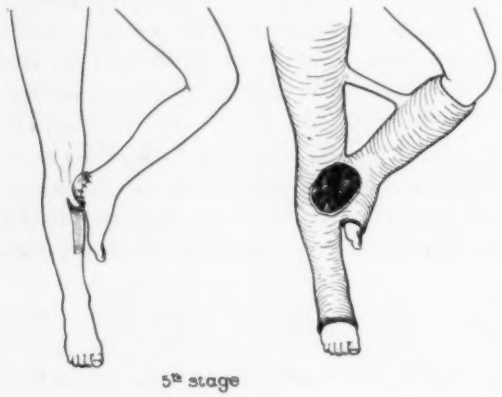

FIG. 3

Fifth stage. The distal end of the flap is severed and the graft is sutured to the prepared bed.

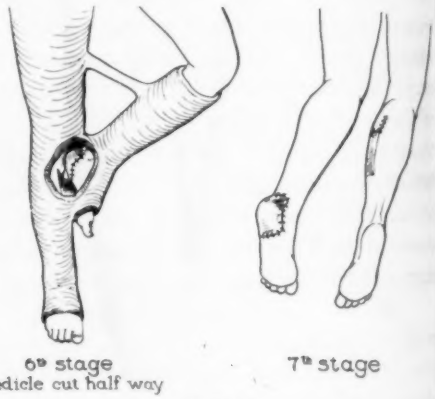

FIG. 4

Sixth and seventh stages of the operation. In the sixth stage, the proximal end of the pedicle is cut halfway across, and then is sutured in its original position. In the seventh stage, the proximal end of the pedicle is severed completely, and the remaining portion of the graft is sutured in its new position.

procedure usually is produced by the intravenous injection of a solution of pentothal sodium.

Second Stage: Ten days after the completion of the first stage of the procedure, the sutures are removed and the flap is elevated by blunt dissection. It again is sutured as it was in the first stage (Fig. 1). A Penrose drain is inserted beneath the center of the flap. This drain is removed at the end of forty-eight or seventy-two hours. A pressure dressing is applied at the end of this stage.

Third Stage: Ten days after the completion of the second stage, the sutures are removed and the flap again is elevated. A split graft, which has been removed from one of the thighs with the Padgett dermatome, is sutured under the flap. The flap then is sutured as it was in the previous stages (Fig. 2), but a Penrose drain is not inserted. A light pressure dressing is applied. Intravenous anaesthesia usually is employed for this stage of the procedure.

Fourth Stage: Ten days after the completion of the third stage, the distal end of the flap is clamped lightly with a curved hemostat. If the circulation in the flap is not embarrassed, the flap is cut halfway across at its distal end. Before this is done, the site of the proposed incision is infiltrated with a 1 per cent. solution of procaine hydrochloride. The incision is closed with two or three interrupted sutures (Fig. 2). At this time, or

three or four days thereafter, a long plaster cast is applied to the extremity on which the flap is situated, and a short cast to the knee is applied over the defect on the opposite extremity. A large window is cut over the flap, and a similar window is cut over the defect.

Fifth Stage: About three or four days after the completion of the fourth stage, all of the sutures in the flap are removed through the window in the cast. If the circulation in the flap is adequate, the other half of the distal end of the flap is severed. Anaesthesia is produced by infiltration with a 1 per cent. solution of procaine hydrochloride.

At this time, it usually will be found that the split graft has taken firmly. In this case, the legs of the patient are draped and general anaesthesia is induced, usually by the intravenous administration of a solution of pentothal sodium. The defect is excised, and bleeding is controlled. The under side of the free end of the pedicle graft is freshened until normal fat is reached. The pedicle graft then is sutured to the prepared bed at the site of the deformity with interrupted sutures (Fig. 3). At this point in the procedure, it is important to avoid tension, pressure, or kinking of the graft, as any one of these is liable to interfere with the blood supply of the graft.

A light pressure dressing then is applied over the end of the graft that is fixed in its new position. All raw surfaces are covered with petrolatum gauze. The casts are firmly bound together with rolls of plaster bandage and with board splints that are reinforced with plaster. A window is then cut directly over the defect. The defect and the superimposed graft are inspected to make certain that there has been no change in the position of the graft which would interfere with its circulation. During the next twenty-four hours, the graft is inspected two or three times. If any alteration is necessary, it should be made before it is too late to do so. It usually is impossible to cover the defect fully at this stage of the procedure, but as much as possible of the under surface of the graft should come in contact with the prepared surface of the defect. During the next three weeks, the dressings are changed as necessary, depending upon the amount of drainage.

Sixth Stage: Three weeks after the completion of the fifth stage, the graft usually will be found to be firmly attached to its new bed. With the aid of local anaesthesia, the proximal end of the graft is cut halfway across (Fig. 4), just as was done with the distal end in Stage 4. The incision then is closed with interrupted sutures.

Seventh Stage: In the usual case, the remaining portion of the proximal end of the graft is severed three or four days after the completion of the sixth stage of the procedure. Local anaesthesia is employed for this purpose. If there is little or no infection, general anaesthesia is induced by the intravenous administration of a solution of pentothal sodium, and the uncovered portion of the defect is prepared for the reception of the rest of the graft. The under surface of the proximal portion of the graft is trimmed and beveled so that it will fit into the bed that has been prepared for it. The graft is sutured in position and a pressure dressing is applied. The defect caused by incising the proximal pedicle of the graft is closed neatly by a plastic procedure.

In cases in which a considerable degree of drainage is present when the pedicle of the graft is severed, it may be necessary to use local applications for a few days before the graft finally is sutured in place. Warm physiological salt solution, an 8 per cent. solution of sulfanilamide, a saturated solution of boric acid, or a 1-to-1,000 solution of para-tertiary-octyl-phenoxy-ethoxy-ethyl-dimethyl-benzyl-ammonium chloride monohydrate (phemerol) is used.

The sutures usually can be removed at the end of ten to fourteen days, and the patient may be permitted to walk on crutches in about three weeks after the completion of the operation. Weight-bearing should be begun gradually. In cases in which the graft is too thick or does not fit as well as one might desire, a plastic operation can be performed at a later date.

Parts of the Technique Which Require Special Emphasis: Great care should be taken in outlining the proposed graft in the initial stage of the procedure. If the graft is not

obtained from a suitable site, is not properly planned, or the size of the graft is not correct, difficulty will be encountered when the graft is transferred to its new site. In estimating the length of the pedicle, one should make allowance for the thickness of the casts and also for some oedema and swelling, as well as for some shrinking. A pedicle that is too long is more desirable than one that is too short.

Poor results usually are due to one or more of the following causes: (1) improper selection of patients for the procedure, (2) hemorrhage beneath the graft, and (3) infection. If difficulty is encountered, one should not hesitate to delay the next stage of the procedure. Contraction of the pedicle can be prevented in the interval, and such a delay frequently improves the condition of the graft in cases in which it is not satisfactory. Haste to complete the procedure and shortening the intervals between the various stages usually spell disaster.

FIG. 5-A FIG. 5-B

Fig. 5-A: Actinodermatitis with ulcer on plantar surface of foot.
Fig. 5-B: Appearance of foot fifteen months after repair; there is a slight redundancy of the pedicle of the graft.

Sharp kinking or twisting of the pedicle should be avoided. Care also should be taken to see that the casts do not make pressure on sensitive regions. Pressure by the cast may cause paralysis of the external popliteal nerve. Cutting away portions of the cast to relieve pressure may weaken the cast and cause trouble.

POSTOPERATIVE CARE

The postoperative care of this type of graft does not differ essentially from that of any other type of skin graft. The graft should be kept clean and should be bathed with alcohol to harden the skin. The split graft that was applied to the site from which the pedicle graft was removed should be kept soft and pliable by the daily application of an emollient for six months to a year after the completion of the operation.

CLINICAL DATA AND RESULTS

This operation was first performed at the Clinic in 1934. Between that time and January 1, 1943, the operation was performed in forty-four cases. It was started in four additional cases, but had to be abandoned, after completion of the first or second stage, because of hemorrhage or necrosis. In four of the forty-four cases, the patients had bilateral defects and the operation was performed for the correction of each of these defects; in other words, the operation was performed forty-eight times in forty-four cases, not including the four cases in which the procedure had to be abandoned before it was completed. In more than half of the cases, the operation was performed in 1941 or 1942. This operation is being used with increasing frequency at the Clinic. Improvement in the technique and in the selection of patients has given better results and decreased the incidence of complications.

In the forty-eight cases in which the operation was started, twenty-nine of the patients were males and nineteen were females. The ages of the patients ranged from thirteen to sixty-six years, and the average age was thirty-four years.

The site of the lesion was as follows: the knee in two cases, the leg in seven cases, the Achilles tendon in four cases, the heel in nine cases, the plantar surface of the foot in

eleven cases, the dorsal surface of the foot and the anterior surface of the ankle in four cases, over the external malleolus in three cases, over the internal malleolus in five cases, and an amputation stump in seven cases. Bilateral lesions were present in four of the forty-eight cases. The defects were the result of the following conditions: trauma in nineteen cases, actinodermatitis and ulceration in nineteen cases, trophic ulcers in four cases, infection without preceding trauma in four cases, stasis ulcers secondary to thrombophlebitis in two cases, electric burns in two cases, an ordinary burn in one case, and plantar warts in one case.

FIG. 6-A FIG. 6-B

Fig. 6-A: Traumatic ulcer of ankle due to compound fracture.

Fig. 6-B: Appearance of ankle three months after application of graft.

In eighteen cases, pinch grafts or split grafts previously had failed. In one case, eight grafting operations had been performed. In another case, pedicle-grafting had been attempted, but had been abandoned.

In thirty-three of the forty-eight cases, including the four cases in which bilateral defects were present, the graft was obtained from the calf. In the remaining fifteen cases it was obtained from the thigh.

The average period of hospitalization in the forty-four cases was 90.9 days, or 81.6 days for each graft. The average time required to complete the procedure in these cases was 93.2 days, or 83.7 days for each graft. In several instances, a rather prolonged period of hospitalization was necessary, because of infection which had to be treated before the various stages of the procedure could be undertaken. A number of patients were not in the Hospital all of the times between the various stages of the procedure. In the four additional cases in which the procedure was started but discontinued, the average period of hospitalization was 21.5 days.

The percentage of the total area of the graft that united with the underlying tissues was recorded in thirty cases; this percentage was found to be 92.5.

In the forty-four cases in which the procedure was completed, the results were as

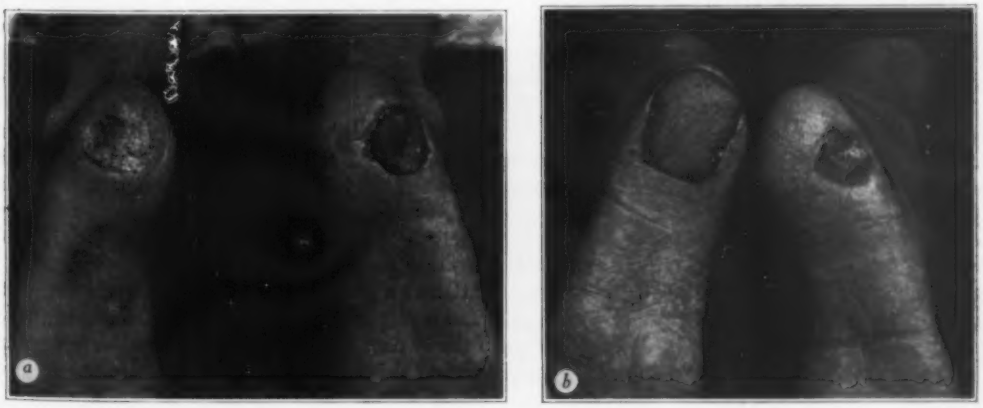

FIG. 7-A FIG. 7-B

Fig. 7-A: Actinodermatitis with ulceration of both heels.

Fig. 7-B: Appearance of heels four months later; a pedicle graft was applied to the left heel, but a split graft was applied on the right side as the weight-bearing surface was intact.

FIG. 8-A

FIG. 8-B

Fig. 8-A: Extensive ulceration caused by thrombophlebitis; pinch grafts and split grafts had failed to produce permanent healing on several occasions.

Fig. 8-B: Result obtained with pedicle graft. A pedicle graft had been applied to the opposite ankle two years previously.

follows: good in thirty-three cases, including the four cases in which bilateral defects were present; fair in four cases; and poor in seven cases.

Poor or fair results frequently are due to the sloughing of part of the pedicle late in the course of the procedure. This may be due to infection or to inadequate circulation resulting from trauma, from tension or kinking of the pedicle, or from hemorrhage beneath the pedicle. One should remember that firm pressure on the graft is one of the best ways to prevent hemorrhage. This is one of the cardinal principles of skin-grafting.

In order to avoid amputation, one is liable to use this operation in cases in which it is not likely to succeed. A proper selection of cases can be made only after one has had some experience with the procedure. The operation probably is rarely indicated in cases of trophic ulcer, as the accompanying trophic changes are liable to lead to complications. In cases in which the operation is performed to correct defects caused by excision of a malignant lesion, the malignant lesion is liable to recur; however, this type of skin-grafting is justified in properly selected cases of this type.

Most of the complications that are encountered often can be avoided, if they are anticipated.

DISCUSSION

DR. H. R. MCCARROLL, ST. LOUIS, MISSOURI:

There are three useful types of skin grafts to be considered in reconstructive work of the extremities: the split-thickness graft, the free full-thickness graft, and the pedicle flap. The pedicle flap is essential in the satisfactory repair or covering of two types of lesions: (1) large defects over superficial bones, and (2) defects on the weight-bearing portion of the foot and on the back of the heel. In these areas, the split-thickness or free full-thickness grafts will not tolerate the repeated traumata to which the area is subjected.

The actual technique of shifting a pedicle flap to a foot may be varied according to the individual requirements with equally satisfactory results. I have always used the opposite thigh for the donor site rather than the lower leg. The advantages of this are: (1) The thigh has a heavier bed of subcutaneous tissue, and more adequate padding and protection can be assured; and (2) In girls, an unsightly scar is placed above the knee rather than below, where it is difficult to conceal. The only objection to this variation is the position of extreme flexion required in the corresponding knee during the three to four weeks of immobilization, while the first attachment of the flap heals. When this position is maintained by solid plaster, the patient is not uncomfortable, and I have encountered no difficulty in readily re-establishing normal motion in the joint. All of my work, however, has been in children, and adults may react differently.

Dr. Ghormley has stressed the delayed transplantation of a pedicle flap. This is not essential in the short, broad flaps used in most foot reconstructions. The initial transplantation to the donor area can be safely accomplished at the first operation, which saves the patient hospital time and repeated operations.

It is encouraging to see the question of replacing surface defects discussed in an orthopaedic meeting. I do not wish to imply that an orthopaedic surgeon should be a finished plastic surgeon, but many instances are encountered in orthopaedic work where the combined use of the two specialties is necessary for a satisfactory solution of the reconstructive problem at hand. If the orthopaedic surgeon understands the basic surgical principles involved in the successful handling of skin grafts and knows a few of the "tricks of the trade", a more satisfactory and permanent end result can often be assured, both functionally and cosmetically.

IMMEDIATE APPLICATION OF FREE FULL-THICKNESS SKIN GRAFT FOR TRAUMATIC AMPUTATION OF THE FINGER *

BY H. R. McCARROLL, M.D., ST. LOUIS, MISSOURI

From the Department of Surgery, Washington University School of Medicine, and Shriners' Hospital for Crippled Children, St. Louis

Traumatic amputation of fingers, already a relatively frequent accident in our modern machine age, has assumed a new and still greater position of importance with our accelerated industrial program of the past three years. The use of punch presses, trim machines, loading machines, and numerous other automatic mechanical units, by personnel often new and inexperienced in their operation, is the factor responsible for the increasing rôle which this injury now plays in the field of traumatic surgery. The utmost in care is essential for these fingers, if we succeed in avoiding the needless sacrifice of an additional part of a valuable digit.

Most of these injuries occur in the distal phalanx, and result in a guillotine type of amputation, including all the soft-tissue pad at the finger tip, a part or all of the nail, and part of the bone. The amputation in all cases in this series occurred through the distal phalanx. Several methods are available to the surgeon for handling such an injury:

1. The defect may be left open, and allowed to granulate, ultimately healing by means of scar tissue. This invariably leaves a finger tip in which the scar is tender and adherent to the underlying bone, and which ulcerates easily from even very light trauma on resumption of work. This often necessitates reamputation for preparation of adequate protective skin flaps.

FIG. 1-A

Case 1. Oblique traumatic amputation of the middle finger through the distal phalanx.

2. Immediate additional amputation of the involved finger may be done to permit the preparation of a skin flap on the flexor surface for coverage of the finger tip. The length of a finger is extremely important, and this further sacrifice of a part of a valuable digit is needless and unnecessary. It results in an increased disability rating immediately, and further impairs the function of the finger for life.

3. The finger tip may be buried beneath a pedicle flap raised from the corresponding palm. This necessitates a two-stage operation, prolongs the period of disability, leaves a scar in the palm of the hand which may cause disability in certain types of work later, and affords a more bulky finger tip which may be cosmetically unsatisfactory. A pedicle flap will not always assume the normal shape of a finger tip.

4. The defect may be covered with a split-thickness graft. Grafts of intermediate thickness are too thin to afford adequate protection for the finger tip, do not entirely prevent secondary scarring, and will frequently result in excessive and unnecessary sensitivity.

5. Immediate application of a free full-thickness graft may be done, as described by Reed and Harcourt[1] in 1939. This represents the most satisfactory and most nearly ideal procedure of the lot because:

a. All of the remaining portion of the finger is preserved; no additional sacrifice of valuable finger length is necessary.

* Read at the Annual Meeting of The American Academy of Orthopaedic Surgeons, Chicago, Illinois, January 26, 1944.

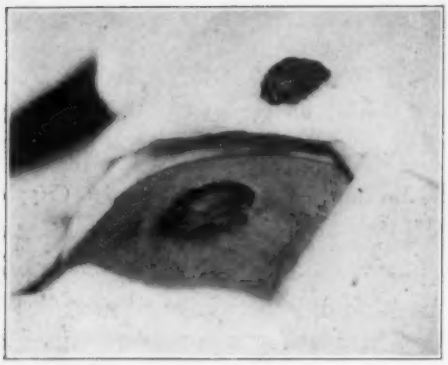

FIG. 1-B

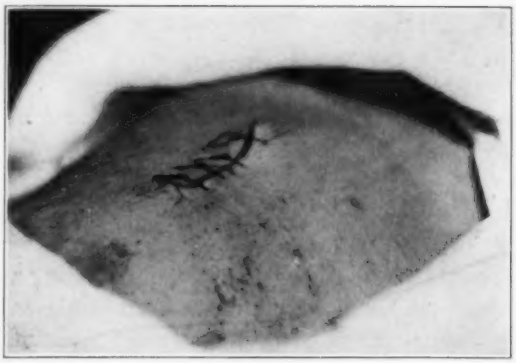

FIG. 1-C

Fig. 1-B: Free full-thickness graft has been removed from the flexor surface of the forearm. The graft lies on the gauze above. Fig. 1-C: The donor area has been closed under tension.

b. It provides the finger tip with an excellent soft-tissue pad which undergoes little or no secondary scarring, prevents sensitivity in the tip, and assumes a smooth well-rounded contour which cosmetically is superior to any of the others.

c. It reduces the period of disability to a minimum. Healing is completed more rapidly, and the immediate dressing is small enough for the patient to be permitted to return to work immediately.

d. The improved function, improved appearance, and preservation of finger length afford a lower disability rating and thus a saving for the employer.

OPERATIVE TECHNIQUE AND POSTOPERATIVE CARE

The involved finger, other than the denuded tip, is cleansed well with soap, water, and ether, and is then prepared with an antiseptic solution, as is the area from which the graft is to be removed. After draping, the denuded tip is cleansed or irrigated adequately with normal saline. A solution of 1 per cent. procaine is injected into the finger through the cut surface. The donor area is then injected with procaine solution and an area roughly the size of a half dollar is

FIG. 1-D

Showing the usual appearance of the scar on the forearm after one year.

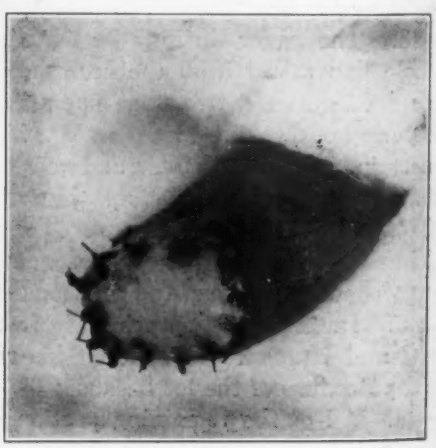

FIG. 1-E

Showing graft immediately after application. Note the sutures through the nail.

raised. Any part of the body may be used as the donor site, but, for convenience, the flexor surface of the corresponding forearm is usually chosen.

If the amputation tip is smooth and the bone does not project beyond the cut skin surface, no further preparation of the field is necessary. However, if the phalanx does project, enough bone is removed with sharp rongeurs to make it flush with the surface of the wound. If there are any loose skin tabs or irregular surfaces, these are excised only sufficiently to ensure a smooth bed for reception of the graft.

The donor area is outlined to correspond roughly to the shape and size of the involved finger tip, and the full thickness of the skin in this area is removed with a sharp scalpel, care being taken so that no subcutaneous tissue is left attached to the graft. The flexibility of skin is such that a graft the exact dimensions of the finger tip is not essential. The donor area is then closed with interrupted sutures of silk.

The graft is placed on the denuded finger tip, so that the dimensions of the two are in nearest accord. It is anchored in place with interrupted sutures of fine silk or horsehair, the sutures first being placed about the lateral, medial, and flexor surfaces. The final sutures are placed on the dorsal surface, and, when the amputation occurs through these

FIG. 1-F

A firm pressure dressing has been applied following operation.

FIG. 1-G

Three months after injury the patient has a smooth, well-rounded finger tip.

FIG. 1-H

Showing appearance of the finger tip three months after injury.

structures, are anchored through the nail, or nail bed if the nail has been torn off. The graft is anchored in place under slight tension, and, if it is too loose, a small portion of the periphery of the graft is excised as the graft is attached. No overlap of the graft over intact skin is permitted; instead, the edge of the graft is approximated accurately to the cut surface of the skin. The graft thus covers accurately the entire finger tip, and is placed directly over the cut surface of the bone without first attempting to pull subcutaneous tissue over the bone.

The most important single factor in assuring the success of any free skin graft is the initial application and maintenance during the first few days of a firm, snug, pressure dressing. A single thickness of greased fine-mesh gauze (usually greased with vaseline or 4 per cent. xeroform ointment) is applied. In some instances, sulfanilamide powder has been dusted on the wound prior to dressing, and in others it has been purposely omitted. (The author has not been greatly impressed by the importance of this step.) Small gauze flats are then moistened so that they will mold more easily, and several thicknesses are placed over the finger tip in both planes. A small gauze bandage is then used to anchor them firmly in place, assuring smooth firm pressure to the entire finger tip. It is not necessary to extend the dressing beyond the base of the involved finger.

A small dressing is applied to the donor site. The sutures are removed from this on the seventh day, at which time the scar looks quite well. Since the defect has been closed under moderate tension, however, the scar ultimately spreads so that the final scar is approximately

FIG. 2-A

Case 2. Guillotine type of amputation through the mid-portion of the nail of the index finger.

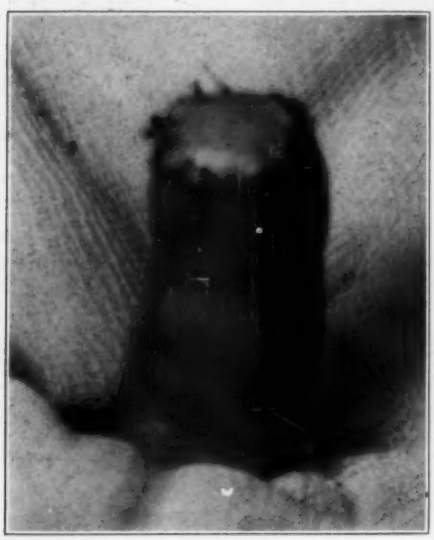

FIG. 2-B

Showing the finger immediately after the application of the graft.

FIG. 2-C

Showing the appearance of the graft after three weeks.

FIG. 2-D

FIG. 2-E

Showing the finger tip after six months. Note the short, but well-formed nail.

the size of an average vaccination scar on the flexor surface of the forearm. The dressing on the grafted finger is not disturbed until the sixth day. Some of the sutures are removed at this time, and some are left until the next dressing three days later. The superficial epithelium on the graft desquamates very early, and most of it can be pulled off at the first or second dressing, exposing the pink viable portion of the graft beneath. This desquamation of the superficial non-viable layer of epidermis invariably occurs, and is of no consequence in any split-thickness or full-thickness graft. The dressings are changed at intervals of two to three days as indicated, and the single layer of greased gauze and the firm pressure dressing are reapplied. Firm pressure is necessary to prevent the collection of serum and elevation of the graft from its bed. It is essential that this pressure be maintained until the graft is well attached and well healed,—approximately three weeks. After that, a lighter dressing may be used. After four to five weeks the preservation of the graft is usually assured. The dressing is then removed by the patient daily, and the

FIG. 3

Case 3. Appearance of finger tip six months after injury in one of the two cases where the graft was lost. Essentially the same type of result is obtained when the wound is not covered, but is permitted to heal spontaneously. Compare this with Figs. 1-H and 2-D

finger is soaked for thirty minutes in warm water; this is followed by exposure to the air for thirty to sixty minutes. This period of exposure to the air is gradually increased each day and serves as a toughening process for the graft. At the end of five to six weeks, the dressing is discarded entirely, except for a small protective covering used while at work. In some instances, near the end of the second week, a small superficial portion of the graft is lost directly over the tip of the bony phalanx. This is never a full-thickness loss of the skin, it is of no consequence, and the area can never be identified after healing is complete.

This meticulous postoperative care cannot be stressed too much; it is an absolute prerequisite for the success of any skin graft.

RESULTS

Forty-five consecutive cases of traumatic amputation of the finger have been treated by immediate application of a free full-thickness graft. Of these forty-five cases, forty-three have shown complete "takes" of the grafts. Each has shown a smooth, well-rounded finger tip, soft, non-adherent, non-sensitive, and satisfactory in appearance; in each instance the patient has been able to return to his former occupation. He also has been able to work during the period of his postoperative care, since only the involved finger was incorporated in a dressing. The remaining two cases are classified as failures with loss of the graft, although in neither instance was the graft a hundred per cent. loss. Each retained enough of the graft to aid in filling in the defect, and in decreasing the period of disability, although there was an increased amount of scarring over the finger tip, which was adherent to the underlying structures. Sensitivity was not sufficient in either case for the patient to elect a secondary amputation with preparation of adequate skin flaps.

These results with complete "take" of the graft in 95 per cent. of the cases have been such that continuation of the procedure described by Reed and Harcourt is justified. In fact, the author feels that immediate application of free full-thickness skin grafts should be considered as the procedure of first choice in the correct management of traumatic amputation of the finger.

1. REED, J. V., AND HARCOURT, A. K.: Immediate Full Thickness Grafts to Finger Tips. Surg. Gynec. Obstet., LXVIII, 925, 1939.

THE PLACE OF GLASGOW IN THE HISTORY OF ORTHOPAEDIC SURGERY *

BY A. K. BOWMAN, M.D., GLASGOW, SCOTLAND

It may seem something of an affront to you that I, a mere physician, untutored in and unfamiliar with the orthopaedic art, should speak to you at all; and certainly it would be a matter for grave personal reproach if I suggested that in the time allotted to me I could present to you, even in the barest outline, a picture of the place which Glasgow occupies as a cradle of orthopaedic principle and practice. Your presence here, however, indicates that you are prepared to be kind; and I beg you, therefore, to look charitably both on my own lack of qualification and upon the checks which the hour imposes upon me.

I want to say something concerning the foundations and the groundwork which were laid for orthopaedic surgery by three men whom we, in this part of the country, regard as Glasgow men, although the birthplace of none of them is to be found within the city limits.

In peacetime, in the University of Glasgow, there recurs at intervals a ceremony, or ceremonial, or, to use the American language, an exercise, known as the Commemoration of Benefactors. On this occasion, those who are present may, according to their own interests and after their own fashion, bend their thoughts to the achievements of the human mind which have come to birth in, or near, the shadow of the University. Upon the roll of honorable names which then lies open for our examination are those of the three great men with whom we are chiefly concerned today,—John Hunter, Joseph Lister, and William Macewen. If it be the case, as may undoubtedly be claimed, that the influence upon surgery of this triumvirate is unique and unexcelled by that of any similar company of men, then, under the axiomatic rule of mathematics that the greater includes the less, it follows that the combined work of Hunter, Lister, and Macewen is the most important contribution which has at any time been made to the specialized domain of orthopaedics. To reach this conclusion, however, it is not necessary to invoke the aid of any mathematical law, for the conviction emerges with equal distinctness from a consideration of the work itself. I hope that the few details to which alone I shall be able to refer will justify this claim.

As a good Scotsman, it might be expected that I should be unable to resist the temptation to draw attention to the fact that, of the three names on our list, two are the names of Scotsmen, or to add that this ratio of two to one in favor of Scotland is exactly what might be expected to appear upon a British roll of honor; but I refrain from doing so, not only because of the respectful restraint which the name of England imposes, but also because the numerically superior Englishmen among you would naturally institute a pincer movement and remind me that, of the three men in question, John Hunter chose to make his fame in London, while Lister, to all intents and purposes, was driven from both Glasgow and Edinburgh by the intolerable antagonism and jealousy of his Scottish colleagues. Of all three men, Macewen alone remained throughout his long life in Glasgow. He was a hardy man, whom no bleakness of the elements or of the hearts of his fellowmen could chill. Here he remained, strong, self-reliant, absolute; and, in the words of Harvey Cushing, he manifested here, at home, all the peculiar instincts, boldness, and enterprise of the intrepid pioneer.

Of the work of Hunter, Lister, and Macewen you, as orthopaedic surgeons, are all sufficiently familiar to make it unnecessary to speak except in the most general terms. I shall, therefore, try to follow it, briefly, only in its immediate wide relation to your own special field. Hunter is the natural starting point, and it may perhaps be as well to point out here that John Hunter, who has to such a great extent stolen the thunder of the Hunter

* Read before The British Orthopaedic Association, in Glasgow, Scotland, May 14, 1943.

family, was, while the better known, perhaps only the equally great of the two brothers Hunter. Macewen, indeed, looked upon William Hunter as in some respects the greater of the two; and he also pointed out, no doubt with justice, that had there been no William, there would have been no John Hunter. Accordingly, in speaking of John, we should have William constantly in our thoughts as a power behind the throne; and it should also be remembered that the Glasgow Hunterian Collection was bequeathed to the University by William Hunter, not by John.

Instead of following his brother to school and ultimately to the University at Glasgow, John Hunter remained at home, untaught in any formal way, until he was twenty years of age. He seems to have resisted the idea of schooling, and was accordingly apprenticed to a cabinet-maker and carried on this trade until, in 1748, awakened by some stirring of the soul, he followed William to London and became his laboratory assistant. Regarded from the point of view of early influences, his work in carpentry is interesting, because it recalls that similar forces connected with the use of the hands were operative in the cases of both Lister and Macewen. The former had in his father an expert microscopist and technician, and there is no doubt that at an early age young Lister's fingers became accustomed to delicate manoeuvres. Macewen's home life in childhood was conditioned by the sea-faring occupation of his father, and he himself commonly attributed much of his manual dexterity to the handling of shipwright's tools in a small yard on the Island of Bute.

Hunter's arrival at his brother's quarters in London was followed by his spectacular rise to distinction as an anatomist, biologist, and surgeon, and as a worker who spent himself and his earnings prodigally in the pursuit of his investigations. It may not be amiss if we describe John Hunter at once, as Osler and Macewen did, as the most remarkable observer of nature since Aristotle,—a man with wider and more scientific conceptions and sympathies than had ever before been united in a member of our profession, and whose fundamental notions of disease are only now, perhaps, becoming prevalent.

You will understand that it is impossible for me, unhappily unfamiliar as I am with the finer problems of orthopaedics—even with that interesting and, I am informed, elementary controversy which centers around Syme's amputation—to select from John Hunter's work the points of his teaching which may be of the greatest interest to you. There are, nevertheless, certain aspects of the work which cannot fail to impress their momentous message upon the mind of even the uninitiated, and no doubt you will be content if I speak of one or two of these.

In the first place, the attention cannot fail to be powerfully arrested by the great general principle which may be looked upon as Hunter's profoundest contribution to biology,—namely, his clear recognition of the fact that life, or the living principle, is the most complex concept in all nature, because no other concept is so complex in its effects. Associated with this concept in Hunter's mind, and following from it in its immediate surgical relations, was the fact that restoration or repair is effected in living tissues by powers inherent in the tissues themselves. The surgeon can only aid recovery by recognizing, acknowledging, and fostering these powers. Hunter had no hesitation in berating the conceit of surgeons who thought themselves possessed of abilities superior to those of Nature, and here Macewen was peculiarly at one with him. "It was a pity", said Hunter, "a crime", said Macewen, "that the surgeon should try at times to become something more than Nature's mere assistant". The surgeon, of course, had his uses, and no doubt Nature was grateful for his help. He could uproot weeds and lop off rotten branches, and thus ease the strain; but the power of growth and repair did not lie within his grasp. Hence it was that Hunter and Macewen again found themselves on common ground in asserting that injudicious and ill-considered surgery was capable of producing untold harm. Simplification and judgment were the watchwords which directed all their labors, and both upheld in their own lives and practice the Hippocratic injunction, "not to do

harm". What was done by operative intervention could not be readily undone. Tissue excised was usually tissue irretrievably lost, though not invariably irreplaceable. Hunter, speaking with a deep consciousness of the physician's point of view and of the function of medicine as opposed to that of surgery, declared that "to perform an operation is to mutilate a patient we cannot cure, and so an acknowledgment of the imperfection of our art". This consideration was, of course, influentially in his mind when, in defiance of the gravely stated views of his associates, who preferred the method of amputation practiced by Percival Pott, he elected to ligate the artery in cases of popliteal aneurysm.

If it be true, as many influential surgeons have believed, that a knowledge of the muscles and of muscle action is at once the beginning and the end of orthopaedic treatment, then John Hunter merits our attention more than any other surgeon. I do not propose to argue one way or another upon a subject upon which I am unqualified to speak; but it is proper to point out that Hunter's view that bone deformity was essentially due to muscle action held almost unchallenged sway for one hundred years, more or less. After this time, Sir William Jenner and Macewen, working independently on the problems of rickets, modified Hunter's views in some particular directions by demonstrating that in most cases of rickets the muscle tone was too low to produce the gross deformities which were commonly encountered. Pursuing his investigations, Macewen later came to the conclusion that the same consideration applied to talipes, and that in both types of deformity the fundamental cause of the condition lay in the bones themselves. Studied from the standpoints of pathology and of pure logic, Macewen's arguments appear to be too sound to be refuted; but nothing that he says detracts from the nobility of Hunter's conception of muscle activity, with which, indeed, in almost all respects and with but few qualifications, he is in full agreement. It may, in fact, be said that Hunter's and Macewen's views are complementary to each other and that, taken together, they present a true and complete picture of the principles of muscle activity. Thus it is probably correct to say that, while Macewen denied, for example, the primary etiological relation to anterior tibial curves of a shortened gastrocnemius and contracted tendo achillis, and held that the factors determining the deformity were to be found in the weight of the body and the force of gravity acting on the softened bone, he simultaneously acknowledged that the reaction in the soft tissues, the shortening and the contraction, might be looked upon as a partial proof of Hunter's contention that the muscles were the most educable structures in the body.

Although the desire for aesthetic anatomical results, which satisfied their hearts, was dear to the orderly minds of both men, each realized that to the patient, and so to the community, it is function and not structure which is important. Accordingly, it was the means toward functional rather than structural results of treatment to which they turned their thoughts and bent their energies. Perhaps in this respect Macewen was somewhat the greater of the two. His search for physiological data was always more keen than that of Hunter, and he felt that he had abused a trust if he neglected, at any operation, to search deliberately for evidences which might enlarge his knowledge in this field. Thus he developed with great nicety Hunter's conception of the minimum load for muscles, and in his later years few things provided him with greater interest or pleasure than to devise graduated active exercises for the victims of the last Great War,—exercises which not only developed and re-educated opposing groups of muscles, but which were calculated to provide an essential stimulus to mental rehabilitation, without which any effort of the orthopaedic surgeon must be reduced to vanity.

It must be clear to you that I find it difficult to dissociate Macewen from John Hunter, for he was, I think, the greatest inheritor of the Hunterian benefaction; and the mention I have just made of opposing groups of muscles reminds us that, while Hunter was not the first to realize that it is impossible for a muscle or a muscle group to contract, unless the opposing group is called into action simultaneously, he certainly appreciated far more than anyone had done before him that the relaxation of the extensor muscles is just as impor-

tant, as real, and as vital an act as the contraction of the prime movers, the flexor groups. From the practical point of view, it was no disadvantage to him that he remained in ignorance of the mechanism which regulates the action of the antagonists. What was of great moment, not only to him but to all his successors in the field of surgery, was his recognition of the principle of coordinated muscle action, and of the cardinal importance of this activity upon bones in "a state of unsoundness", no matter whether the latter resulted from violence or from disease. Although, as Macewen declared, there may be exceptions to the general rule, Hunter recognized this factor of unsoundness to be a consideration of the first magnitude in the practice of bone surgery, because, in the state of softening, the bones may be molded and adjusted to react to the muscle stresses to which they will be subjected.

Year by year John Hunter's wisdom grew, and his knowledge of the art of surgery increased. It cannot be said of him, as it must be said of most workers in the scientific sphere, that his best work was accomplished before he reached the age of forty. In this alone he stands out above his fellows. Until his death he continued to search for truth, and to find the clue to it in many obscure and complicated investigations. That is important enough; but what is of still greater importance to us, if we seek in Hunter's life a model or an object lesson, is the fact that, as his art ripened, his opinions and conclusions changed. His mind was so dynamic that it abhorred stagnation. Not for a moment would he countenance the fixed idea, or tolerate the inflexible outlook. "Never ask me", he cried, "what I have said or written; but ask me what my present opinions are and I will tell you!" And again when Sir Astley Cooper, as a medical student, reminded him that in a previous year he had expressed a different opinion, "Very likely", he replied, "I hope that I grow wiser every year".

When we speak of Joseph Lister and recall his profound yet simple and kindly personality, we of this generation seem to become instinctively aware of the aura of immortality which invests his name. Yet, although every operation we perform is a monument to Lister, it is at all times difficult for us to appreciate the immensity of Lister's work. Even under conditions of war, we do not see gross evidences of the evil which confronted him during his early days in Glasgow—evil which was common to every civilized community and which drove the surgeon to despair, and his patients, as often as not, directly to the grave. Although his strictly local contributions to orthopaedic surgery—his work, for example, on osteotomy and the patella—are by no means to be neglected, you will appreciate that they must be neglected here, for they pale into relative insignificance when viewed against the massive background of Lister's great benefaction to the common good,—the antiseptic system. Clearly, this system was itself the greatest contribution ever made to orthopaedic surgery, for we must not forget that it was an orthopaedic problem, the needs of the compound fracture, which called it into being.

For us, it is almost easier to imagine a world without an England than to picture the practice of surgery without a Lister; and it is even difficult to grasp the fact that it was as late as 1860 that Lister came to Glasgow as the Regius Professor of Surgery. In 1864, aided in some details by Thomas Anderson, his colleague in the Chair of Chemistry, he launched, from the springboard of the Royal Infirmary, the antiseptic system upon the flowing tide of surgery.

The results of the combined work of Black and Watt, also of Glasgow, are clear to all of us. They gave a tremendous impetus and momentum to the development of the industrial age, the pressure of which, by the middle of the last century, was leading to an increasing morbidity and mortality through accident, to a degree which was alarming. The restless audacity of the great surgeons of that time—and none can deny that they were great in the heroic sense—was unequal to the task of stemming the tides of death, which daily lapped around their working places. The circumstances of the time were cruel. All over Europe, and in America also, hospitals were threatened with closure because of the

plague of sepsis which afflicted them. The slightest wound, particularly if it were treated in a hospital, was the potential messenger of death; and, even under the best conditions, a 50 per cent. mortality in compound fractures was the rule. In institutions, erysipelas, hospital gangrene, pyaemia, and septicaemia held almost undisputed sway. In the more crowded hospitals at large, of which the Glasgow Royal Infirmary was one, and especially in military hospitals, and most of all on naval hospital ships, the patient sank almost inevitably under the suppuration of a compound fracture. The wave completely engulfed him, and the following contemporary description of the common clinical course in compound fractures is enlightening:

"The dry skin, the parched mouth, the thumping pulse, the restlessness and delirium, continue for some days, and there is a blackness round the wound, threatening gangrene. But this fever by degrees becomes less violent, the lividity, which proceeded partly from ecchymosis and partly from the dark color of the inflammation, gradually changes to green, the great wound begins to suppurate and open very wide, the whole limb swells to an enormous degree, the skin and cellular substance are soft and relaxed, the redness extends all over the limb, and from the particular hollowness and softness of certain points you are sensible that great suppurations are forming within. Often, all your cares are unavailing. The muscles are all undermined and the bones carious. You find that you are no longer able to support the patient's strength. He is reduced to extreme weakness, and the wan visage, the pale and flabby flesh, the hollow eyes, and the prominent cheek-bones, the straggling and squalid hair, the long bony fingers and the crooked nails, the short quick breathing, and small piping voice declare the last stage of hectic fever and debility."

Such was the enemy which faced Lister in the Royal Infirmary, and Lister's soul rebelled against what he beheld. Although the devastating results of massive sepsis were no doubt much less marked in ancient times, and even in Hunter's time, we may say with much assurance that what Lister saw in compound fractures was much the same as Hippocrates saw and described twenty-four centuries ago,—namely, that the patients generally died, and that "it is a spasm that kills them". We can only ascribe Lister's conquest of sepsis to that quality of mind which, when confronted by the evidence of centuries, presented with immense authority and all the conservatism of custom, rejects the apparently inevitable conclusion and questions, "But is it really so? And is it so to me?" We must remember that Lister's system was founded, not upon observed facts as to causation, but on a pure hypothesis; and, realizing this, we marvel even more at the tremendous faith and stature of the man. For generations past it had been held that local suppuration and all its terrible sequelae were the direct results of atmospheric contact with the wound; and this belief, in spite of John Hunter's condemnation of it a century before, still held the field. Even after the successful demonstration of the use of antiseptics, conservatism maintained its place, and Lister, as you know, was derided and besmirched, and well-nigh pilloried, and accused of the practice of the charlatan. With the exception of a devoted and enlightened few, of whom Macewen took the lead, even among those who granted that Lister's treatment was effective, and even among those who became his followers, it was generally denied that micro-organisms could have any causal relations with disease, and it was held by them that the beneficial results were due to the coagulative action of carbolic acid, which led to the insulation of the tissues from the air.

As we shall see, it was left to Macewen to vindicate the Listerian hypothesis, and it is gratifying to Glasgow men to remember that the corner stone was set in the same institution in which the antiseptic system came to birth. In the whole of history, I know of no example more striking than that of Lister in which a human spirit rose to meet a fateful hour. Well may we read the words inscribed upon his tomb in Hamstead Cemetery, although we may doubt whether he himself would have chosen them for his epitaph: "And all generations shall call me blessed".

It is almost correct to describe Macewen as a Glasgow man, but actually he was born on the Island of Bute. From the age of fifteen, however, his residence was in the city, where he went to school for a time. John Hunter, by reason of the teaching given by his brother William, may be said to have been vicariously a student at Glasgow; but Macewen

was, of course, an actual graduate of the year 1869. As a senior student he was one of Lister's dressers, and immediately after graduation he plunged headlong into that great series of investigations which have been fraught with such significance for science and for man. At the age of twenty-eight he became surgeon in charge of wards in the Royal Infirmary. In 1889 his reputation was so established that he was asked, or rather entreated, to go to Johns Hopkins University to become the first director of the Baltimore School of Surgery; but, in spite of the most inviting gestures, he chose to regard the claims of his patients in Glasgow as his first responsibility, and declined the offer and the honor. Thus it was that, in the year 1892, when he was forty-four years of age, he was appointed to the Regius Chair of Surgery at Glasgow; and in the same year he moved from the Royal to the Western Infirmary. The years which intervened between the graduation and the professorship were charged with work of such volume, quality, originality, and precision that, as Dr. Charles Mayo said, it could only have been carried out by a human dynamo regulated by genius. That is as good a description of the man as any.

Perhaps few men in the past have had a clearer picture in their minds of the ideals of orthopaedic surgery, yet one could not pin Macewen down to a statement of belief in orthopaedics as a speciality. He was, indeed, somewhat distrustful of the specialist, by whom, he felt, the cardinal principles of medicine might be neglected. For himself, he sailed the high seas of general surgery, and coasted when he would along the shores of physics and biology, mechanics and engineering. The restricted fairways of even two or three specialities were too narrow for him. Properly, it might be said that he made a speciality of everything he touched; and thus, when we glance at the record of his work, we are confronted by the phenomenon of the master hand occupied, not successively but simultaneously, with the brain and spinal cord, the cranium, the ears, the throat and nose, the bones and joints in their physiological and pathological relations, the thoracic and abdominal cavities, and so on; and we are forced to the conclusion that here was a superman indeed.

If Macewen had as his domain the open sea of surgery, no one will deny that his means of travel was impressive too. To borrow from Sir Arthur Keith, whose words are otherwise applied, Nature had given the ship he sailed ample lives and a heavy armament, and he could, and did, use her for fighting purposes. He sent many a warning shot across the bows of contending craft; and, if this were not enough, every now and then a deliberately hostile broadside would break forth with shattering effect. For by far the greater part, however, he used his ship not for his own ends, either in fighting or in profiteering, but rather for rescue purposes; for, in common with Hunter and Lister, he regarded himself as nothing more than a humble servant of Nature, whose only honest function was that of putting something into life, not that of taking from life what he could. It was inevitable that, again like Hunter and Lister, he should encounter bitter opposition, and essentially, as all men must, he lived a lonely life. He recognized that, while commonplace work can be understood by many, original conceptions can be comprehended only with effort, and are, therefore, usually unregarded or, if noticed, are condemned. Fortunately, it mattered little to him how his teaching was received; for, as he indicated in his inaugural address at Glasgow University, he was working, "not for the day that passes, but for the eternity which surrounds us".

We may glance only for a moment at a few of the freights which he brought to shore. In the first place, he was the most prominent and no doubt also the most militant of Lister's disciples in the propagation of the doctrine of antiseptics; and Lister himself, conscious of that discipleship in one who acknowledged few men to be his master, and grateful for the massiveness of the armament which Macewen's advocacy lent to him, was not slow to make a characteristically graceful acknowledgment. But Macewen was never content merely to advocate the teaching of another; and thus almost from the beginning his efforts were directed toward the ideal of an aseptic, as distinct from an antiseptic surgery.

It will be remembered that one of the great obstacles to the acceptance of the germ

theory of disease was that, for fifteen years after the statement of his belief by Lister, no specific confirmation of that belief was to be found. The sign presented by the virtual transformation of surgery in Lister's and Macewen's hands, not to mention those of others, was not enough. In the year 1879, however, Macewen demonstrated the presence of micro-organisms in pus, and the Listerian teaching passed from the realm of hypothesis into that of fact. Simultaneously, Macewen's operative technique became wholly aseptic, and in his monograph "Osteotomy with an Inquiry into the Aetiology and Pathology of Knock-Knee, Bow-Leg, and Other Osseous Deformities of the Lower Limbs", published in 1880, he speaks of it as such.

Although the status of asepsis was thus officially established, it is not clear that the results of Macewen's work on bone were appreciably affected by the formally increased stringency of his control. From the very beginning, indeed—that is, in the years from 1870 onward—his practice in clean operative fields must to all intents and purposes have been aseptic. When, for example, he presented the records of his first 1800 osteotomies to the International Medical Congress at Copenhagen in 1884, his results staggered the imagination of his audience, and the ovation which he received at the end of his address must have few counterparts in the annals of science. In the whole series of 1800 cases there had occurred not one single instance of septicaemia or pyaemia or other fatal wound complication. There were, in fact, only five deaths in the whole series—from intercurrent diphtheria and the like—and wound suppuration was present in only eight instances. When it is remembered that at this period Lister was still laboring to instill the principles of antisepsis into the apathetic minds of his colleagues, the force with which Macewen's observations made their impact upon his audience is the more readily appreciated. An editorial in *The Lancet* of the time voiced the common feeling which was suddenly engendered: "That one surgeon", it said, "can record a series of one thousand and eight hundred compound fractures—for this is the effect of his operation—without a single instance of pyaemia, or of any fatal wound complication, is a fact that nothing but the more generally known results of scientific wound treatment would make credible".

Since the introduction of the open operation of osteotomy by Key and Lemercier in Europe in 1815, and by John Rhea Barton in the United States in 1826, many techniques had been developed, distinct from that of subcutaneous osteotomy, in the hope of finding an ideal method for the rectification of bone deformities resulting from fracture or disease. It was really a matter of "How many men? So many opinions!" And this was, as ever, an indication and acknowledgment that no operation was in itself completely satisfactory. Yet the matter was one of exceptional importance, because of the prevalence of badly united fractures and of the hideous deformities produced by rickets and the structural abnormalities associated with tuberculosis of the joints. Of all the operations in the field, Macewen most admired that which had been devised by Ogston, the choice of Ogston's line as the site of section appealing to him as a stroke of genius. Nevertheless, he quickly detected the inherent weaknesses of the manoeuvre—the opening of the joint capsule, the filling of the latter with bone dust, the irregular joint surface produced, and the sharp upward projection of the displaced condyle on the inner side of the knee—and he set himself to devise what speedily became the standard operation of osteotomy all over the world. The first antiseptic osteotomies were performed in August 1874, by von Volkmann at Halle; but Macewen followed hard on his heels, and in Glasgow, on April 11, 1875, he carried out the first antiseptic osteotomy in the English-speaking world. This operation was the beginning of what we may call the magnificent elaboration of simplicity in technique which, by the time of the Copenhagen meeting, had captivated all but his most hardened or stiff-necked opponents, and which drew from distinguished surgeons the world over public renunciations of their methods in favor of his own.

If it were possible, I should like to say something of Macewen's work on joints, to tell you of his remarkable observations in relation to transverse fractures of the patella, and

so on; but it is impossible to do more than make one further brief reference to another aspect of Macewen's work on bone, which was as wide, perhaps wider, than that of any other man. The problems connected with the growth and transplantation of osseous tissue provided for him a wide field of abiding fascination.

One of his first major contributions to surgical literature was entitled "An Interesting Pathological Observation on the Life of Bone". The first book he published was on osteotomy; and his last book, "The Growth and Shedding of the Antlers of the Deer", published in 1921, three years before his death, was also about bone. The last work is of special interest, not only because of its association with the subject which won for him the Fellowship of the Royal Society many years before, but also because it seems to complete and round off the long series of antler experiments which were begun by John Hunter in Richmond Park nearly two centuries ago.

In March 1874, while temporarily a member of the Out-Patient Staff of the Western Infirmary, Macewen carried out his first experiment on bone transplantation in a human subject. His work in this field falls into three distinct divisions, each marking a progression in method and technique. First came the phase of heteroplastic transplantation, in which the bony tissues of animals were implanted in the human tissues. By this method, functional success at least was obtained for the first time, but Macewen himself was never satisfied that it was not dense scar tissue rather than actual bone which resulted from his work. There followed a long series of cases, including that classical instance in which the whole of the diaphysis of a humerus was replaced by a transplant in which the cuneiform portions of bone excised at osteotomy were employed to build up bone in other portions,—an example of conservation and economy which naturally appeals to a Scotsman. Finally, there came the standard technique of bone-grafting which Macewen applied to the flat bones, as well as to the long, and which he modified from time to time to meet the needs of individual patients. His methods became the basis of bone plastic surgery which, in his own hands, made so spectacular an appeal to the ordinary men and women of two continents.

Momentous as was Macewen's work as a surgeon, and scientific investigator, his character as a man was equally significant. His mind was insatiable, his spirit unconquerable, and his fire unquenchable, and, in the Latin sense, he possessed all the virtues. It was these latter considerations which prompted Harvey Cushing to speak the following words as a last tribute to him:

> "Could such a triumvirate, for example, as Lord Kelvin in combination with a Macewen and a reborn James Watt as their technical assistant, be resurrected to put their fertile minds to the problems involved in the new techniques of surgery, a second revolution in surgical technique no less startling and significant than that we owe to Lister, might well enough take place."

That is all that I wish to say, except to remind you that the way to progress in surgery, as in the quest for truth, lies in the virtues possessed in common by John Hunter, Lister, and Macewen,—honesty, the will to work, and freedom from sentimentality and from personal ambition. I have tried to show you how well worth while has been the road they traveled—the road which was begun in Ancient Greece and which has been driven, across the centuries, across the continents, and out across the spatial universe by the great soul of man. As to its deeper meaning, and apart from the material achievements which have been set up as milestones of human progress, Macewen said:

> "There are at least two things which we may find: one, not the extent, but a measure of our abysmal ignorance; the other, that if we pursue our quest with a single purpose, in search of truth for truth's sake only, we may get a glimpse of the spirit of Nature, and feel the touch of the Hand that weaves the woof."

INJURIES TO THE LIGAMENTS OF THE KNEE JOINT *†

BY LEROY C. ABBOTT, M.D.; JOHN B. DEC. M. SAUNDERS, F.R.C.S.; FREDERIC C. BOST, M.D.; AND CARL E. ANDERSON, M.D.; SAN FRANCISCO, CALIFORNIA

From the Department of Surgery, Division of Orthopaedic Surgery, and the Department of Anatomy, University of California Medical School, San Francisco

Injuries to the ligaments of the knee joint are of frequent occurrence because of the increasing popularity of such sports as football, baseball, and skiing. Examination of these injuries is too often superficial and cursory, and in the absence of fracture, they are too frequently stamped with the all-inclusive diagnostic label, "internal derangement of the knee joint". The application of a splint or plaster cast until such time as the lesion is judged to have healed, satisfies the attendant, if not always the patient. Rest and fixation, although sound in principle and yielding satisfactory results in the cases where injuries are incomplete or minor in character, often prove disastrous in those patients in whom the supporting ligaments of the knee have been severely damaged. Conservative treatment has its place, but, in the presence of extensive ligamentous damage, is inadequate. To avoid the later development of a painful, unstable joint with recurrent effusions and subsequent arthritic changes, and the attendant permanent disability, a far greater precision in diagnosis and therapy is a necessity in a joint of such manifold complexity.

The purpose of this article is to stress the importance of early and thorough examination of all injuries to the knee joint, in order to establish promptly an accurate anatomical diagnosis followed by the required method of treatment. In addition, it is proposed to describe certain forms of examination which have been found to be of practical value in arriving at the correct diagnosis. This description will deal only with the collateral and cruciate ligaments which, with the capsule, are the most important structures affording passive support to the knee.

A knowledge of the anatomy and function of these ligaments and the mechanism of their injuries is essential for the true interpretation of the lesions. The following description of the functional anatomy of the knee joint and the mechanism of injury is drawn from observations made in the clinics and laboratories of the University of California Medical School, together with a complete review of the excellent and extensive studies recently published by Palmer in Sweden, and Brantigan and Voshell in this country.

THE FUNCTIONAL ANATOMY OF THE LIGAMENTS

The ligaments of the knee have two functions. They guide the joint harmoniously through its normal range of motion, and help to prevent the occurrence of abnormal and unphysiological mobility. In both of these activities, the ligaments act as important members of the "joint team", which includes the ligaments themselves, as well as the articular surfaces, the menisci, the joint capsule, and, most important of all, the groups of muscles which control motion of the knee. Their importance is based upon three distinct properties:

1. The ligaments are exceedingly strong. This is perhaps best shown by the fact that in ligamentous injuries of the knee, the bone to which the ligament is attached is often avulsed while the ligament itself remains intact.

2. The position and attachments of each ligament are of such nature that the

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strength of the ligament is utilized to the fullest possible degree in guiding motion and maintaining the stability of the joint.

3. The ligaments have a rich sensory innervation which allows them to act as the first link in the "kinetic chain", as described by Payr and epitomized in "Hilton's law". At the other end of the chain is the strong group of muscles which move the knee. Impulses arising in the ligaments are transmitted through the central nervous system back to the "effector" muscles, thus maintaining the normal, smooth, coordinated motion of the joint. Abnormally strong impulses, such as are initiated when the ligament is forcibly overstretched, result in contraction of the allied muscle groups, thereby protecting the ligament and preventing further injury and subluxation of the knee. Additional evidence of this rich innervation is seen in the muscle spasm apparent after injuries to the joint.

FIG. 1

Schematic representation of the femoral condyles illustrating their axes of rotation.

Throughout the normal range of motion of the knee, certain fibers of one or more of the ligaments are tense, affording stability to the joint, while the other ligaments, or at least some of their fibers, are relaxed, allowing motion to occur. They are so arranged that, when they are all tense, a condition which exists only in the hyperextended position, no motion of the knee except flexion is possible without ligamentous injury.

In order to understand the function of the ligaments, the types of motion in the knee joint must first be considered.

THE MOTIONS OF THE NORMAL KNEE JOINT

The femur articulates with the tibia through the medium of the two femoral condyles. The plane of the medial femoral condyle is set at an angle of 15 degrees from the anteroposterior vertical plane. Its articular surface is curved in the form of an arc whose center of rotation is lateral to the joint. The lateral femoral condyle is nearly vertical, and its articular surface forms a straight line in rolling. This dimorphism accounts, in part, for the medial rotation which occurs in extension (Fig. 1).

In this paper, all motions and positions of the knee are described as the motion and position of the femur on the leg which is fixed in the upright position.

The two functional types of motion of the knee joint are flexion-extension and medial and lateral rotation. During flexion and extension the femoral condyles not only roll on the top of the tibia, continually establishing new points of contact, but also spin on the same spot on the tibia, the femoral condyles turning, but not moving forward. In addition, the medial femoral condyle moves in another manner during extension. It actually skids backward while turning forward into extension. The two femoral condyles roll, spin, and skid independently of each other, accounting for the rotation of the femur on the tibia. The permissible rotation at any time varies considerably, depending upon the degree of flexion.

Small amounts of accessory, non-functional motions occur or may be manually elicited in the intact knee,—namely:

1. Abduction-adduction rocking of the femur on the tibia, a gap actually occurring between the tibia and femur on either side of the joint.

2. Anteroposterior or sagittal displacement of the femur on the tibia. This may be elicited by pulling or pushing the tibia directly forward or backward on the femur when the knee is flexed.

3. Mediolateral displacement in the frontal plane. This can occur only when the knee is flexed beyond 90 degrees, and in the normal joint this motion is minimal.

In ligamentous injuries to the knee, the range of these non-functional movements may be increased. Clinically, the demonstration of this increased mobility is of great diagnostic importance.

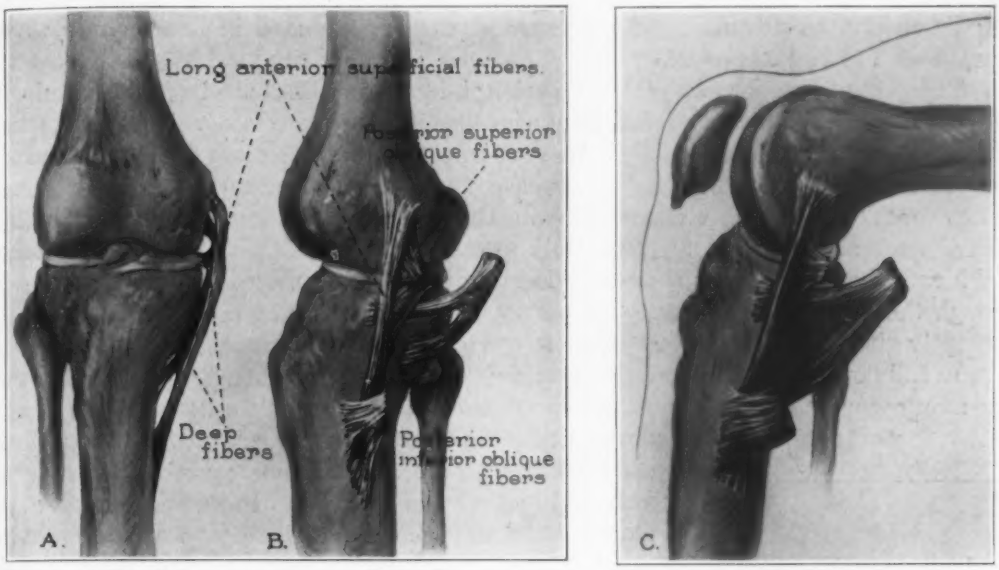

FIG. 2-A FIG. 2-B FIG. 2-C

The tibial collateral ligament in extension and flexion of the knee. (*Redrawn from Palmer, pp. 26 and 27, Figs. 4 and 5.*)

AN ANALYSIS OF THE ANATOMY AND FUNCTION OF THE INDIVIDUAL LIGAMENTS

Tibial Collateral Ligament

The tibial collateral or internal lateral ligament is a far more extensive structure than is usually described in texts of anatomy or surgery (Figs. 2-A, 2-B, and 2-C). It possesses extensions which play a significant rôle in the functional mechanism of the joint, and are of importance in the interpretation of internal derangements. This has been emphasized in the excellent discussion by Brantigan and Voshell. When examined from its superficial aspect, the ligament is roughly triangular in shape and so placed that its base lies anteriorly and its apex extends posteriorly upon the posterior aspect of the medial tibial condyle. For descriptive purposes, the ligament can be divided into four segments although it is a continuous structure.

1. The anterior superficial portion is the part familiarly illustrated. It is a flat band some four inches in length and one-half of an inch in width. It is attached proximally to an ovoid area in the region of the medial epicondyle of the femur. The axis of this attachment is set at a slight angle to the long axis of the femur,—an arrangement of functional value. Some of the fibers can be traced upward to the tendon of the adductor magnus. This portion of the ligament is regarded phylogenetically as the tibial insertion of this muscle. Roughly, the distal attachment is almost one inch in length on the medial surface of the tibia, and lies about one and one-half inches below the line of the knee joint.

2. The anterior deep portion of the ligament lies beneath the superficial part with which it is intimately blended. It consists of short fibers which bridge the joint from the femoral epicondyle to the margin of the tibial condyle, and extend a little distance below. Its presence thickens the more proximal and anterior part of the ligament. It is to this deeply concealed portion of the ligament that the margin of the medial meniscus (semilunar cartilage) is attached.

3. The posterosuperior oblique portion extends from the posterior part of the femoral attachment downward and backward to the margin of the tibial condyle. The tibial attachment is extensive and reaches to the posterior limit of the condylar margin. This part gives additional anchorage to the meniscus.

4. The postero-inferior oblique portion completes the third side of the triangle. Extending upward, it arches over the tendon of the semimembranosus muscle, and, by

blending with the posterosuperior oblique portion, is attached in like manner to the margin of the tibial condyle.

The posterosuperior and postero-inferior oblique portions of the ligament blend with the posteromedial portion of the joint capsule, thus forming a hemispherical pouch. This pouch is lax in flexion of the knee, but in extension it becomes tense as it encloses the posterior part of the medial femoral condyle. The existence of this arrangement requires special emphasis. Grasping in full extension the prominent posterior half of the medial femoral condyle in an accurately fitting "half-bucket", it is a major factor in stabilizing the knee in this position. Destruction of any part of its attachment, even though the long superficial straplike portion of the tibial collateral ligament be intact, promptly gives rise to great instability in the locked or extended position.

In full flexion, the long anterior superficial fibers are tight; hence no abduction rocking may occur and the rotary motions are checked to a certain extent. As the femur moves toward extension, this portion of the ligament begins to relax, while the posterior oblique fibers tighten, and the whole ligament shifts slightly forward in relation to the tibia. In mid-flexion, all of the fibers of the tibial collateral ligament are somewhat relaxed, allowing a few (five) degrees of abduction rocking. As extension proceeds, the long superficial fibers again tighten slightly, and all of the deep oblique and direct fibers become quite tense, so that abduction rocking is prevented and further medial rotation is prohibited. The deep fibers anchor the medial meniscus, so that it is not sucked into the joint with motion.

FIG. 3

Fibular collateral ligament and the tendon of the popliteus. (*Redrawn from Palmer, p. 29, Fig. 7.*)

Fibular Collateral Ligament

The fibular collateral or external lateral ligament, round and cordlike, is attached above to the lateral epicondyle of the femur and below to the head of the fibula (Fig. 3). It divides the tendon of the biceps femoris, from which it is separated by a bursa; more proximally, it is related to the tendon of the popliteus and its synovial sheath. A short distance posterior to the ligament lies a capsular thickening, passing from the head of the fibula to the femoral condyle, and known as the short fibular collateral ligament. This ligament, variable in size, blends with capsular fibers which arch from the fibula over the popliteus tendon to the posterior joint capsule, constituting the arcuate popliteal ligament.

The fibular collateral ligament is relaxed in all positions of flexion. It begins to tighten at about 150 degrees of extension and continues to do so until hyperextension is reached. In the extended positions, it effectively prevents adduction rocking. Although relaxed in flexion, it is an important factor in preventing both medial and lateral rotation (Fig. 4). This is understandable, if we visualize the medial femoral condyle, better anchored by its tight tibial collateral and posterior cruciate ligaments, acting as a hinge about which the femur rotates. The freely moving lateral condyle may glide forward or backward until its anchor chain, the fibular collateral ligament, tightens.

The Cruciate Ligaments

The cruciate ligaments (Figs. 5 and 6) lie obliquely between the condyles of the femur, and it is important to remember that they exist in part in the anteroposterior and in part in the mediolateral planes. The anterior cruciate ligament is attached below to the anterior intercondyloid fossa of the tibia, a little in front of its intercondylic eminence or

FIG. 4

Lateral rotation of the femur in flexion of the knee, checked by the fibular collateral and anterior cruciate ligaments.

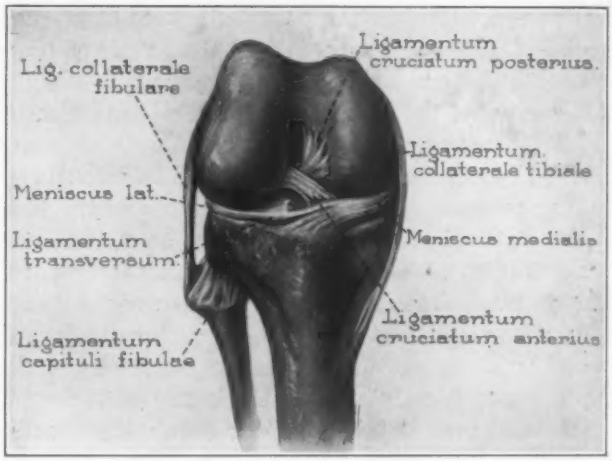

FIG. 5

Anterior view of the cruciate ligaments.

FIG. 6

Posterior view of the cruciate ligaments.

spine. The fibers, passing obliquely upward, backward, and laterally, fan out and are attached above to a concave area of insertion on the medial surface of the lateral femoral condyle. The posterior cruciate ligament, the larger of the two ligaments, is fixed below to the posterior margin of the tibia, and, extending upward in an anteromedial direction, attains its femoral attachment on the lateral aspect of the medial condyle. The femoral insertion of the posterior cruciate ligament, like that of the anterior, is concave, but it is more extensive. The concavity of the femoral insertion of each ligament faces the mid-line of the joint. The femoral insertion of the posterior ligament lies somewhat anterior to, and at a higher level than, the insertion of the anterior cruciate. These peculiarities of attachment result in slight twisting of the ligamentous fibers in their long axis, a twisting which occurs in opposite directions in the two ligaments, as one insertion is the mirror image of the other.

The anterior cruciate ligament is tense in extension and hyperextension. Brantigan and Voshell, in a recent article, stated that this ligament is also taut throughout all degrees of flexion, and that no sagittal displacement of the femur on the tibia occurs in an intact joint. Our observations, and those of Palmer, show that the ligament is under great tension only in extension and hyperextension. It relaxes immediately after flexion has begun, thus allowing greater freedom of motion of the lateral femoral condyle which then rolls backward on the tibial plateau. It remains relaxed until almost complete flexion is reached when some of the long anteromedial fibers tighten. "The anterior cruciate ligament acts as a safety anchorage for the lateral condyle in flexion. Its laxity allows a certain freedom of motion, especially rotation and a small amount of normal adduction locking" (Palmer). A few millimeters of posterior sagittal displacement are also present in flexion.

The tightening of the anterior cruciate ligament in extension, along with the fibular collateral ligament, firmly anchors the lateral half of the joint anteriorly, so that a continuation of the movement into hyperextension can occur only if there is a simultaneous medial rotation of the femur. This is the so-called "final compulsory rotation" of Fick.

It is accomplished by the backward skidding of the medial condyle as the femur rotates medially. This results in a final tightening of the posterior oblique fibers of the tibial collateral ligament and of the posterior fibers of the posterior cruciate ligament, so that a final locking of the joint occurs when all the ligaments are under tension.

The long posterior fibers of the posterior cruciate ligament are tight in extension. Throughout all the flexion, some of the fibers of this ligament are tight, the zone of tension shifting progressively from front to back as the joint moves from flexion into extension. This is made possible by the ligament's long crescentic femoral insertion. This constant tension of the posterior cruciate ligaments results in a better fixation of the medial femoral condyle throughout flexion. This has several definite and important consequences. It shifts the axis of rotation of the femur medially in flexion, greatly limiting the degree of medial rotation and abduction rocking, and practically inhibiting any anterior sagittal displacement of the femur,—that is, the posterior "drawer sign".

In addition to the foregoing commonly described ligaments, the posterior capsule of the joint is reinforced by two expansions, the arcuate ligament on the lateral side, and the oblique popliteal ligament which is an expansion of the semimembranosus tendon. They strengthen the capsule posteriorly and are extremely tight in hyperextension, thus preventing an abnormal range of this motion.

INTERACTION OF THE LIGAMENTS

Although the function of each ligament has been described separately, it must be emphasized that they rarely act individually, but cooperate with each other and with the muscles and menisci as members of the "joint team".

The interaction of the ligaments may best be shown by briefly analyzing the progression of the joint from flexion into extension. In full flexion, the femur lies in lateral rotation. The medial femoral condyle is anchored by the tight posterior cruciate and long superficial tibial collateral ligaments. The lateral condyle is allowed to roll posteriorly because of the laxity of the anterior cruciate and fibular collateral ligaments. As extension proceeds, the medial condyle rolls forward very slightly, but, for the most part, spins on the same spot on the tibia, while the lateral femoral condyle, being more free to move, rolls anteriorly for a considerable distance, causing medial rotation of the femur. The forward motion of the lateral condyle is finally checked at about 160 degrees of extension by the tightening of the anterior cruciate and fibular collateral ligaments. After this point, its motion is limited to spinning. As full extension is approached, the tightening of the anterior cruciate and fibular collateral ligaments securely anchors the lateral femoral condyle, so that continuation of extension is possible only by posterior gliding of the medial condyle of the femur. This accounts for the final compulsory rotation and tightening of the oblique fibers of the tibial collateral, the arcuate, and oblique popliteal ligaments. Thus the knee is finally and securely locked in hyperextension. In this position the cruciates are intertwined.

Anatomicopathological Studies

Extensive studies of injuries to the ligaments produced experimentally in knees of freshly amputated specimens, have been carried out by Palmer of Sweden and Brantigan and Voshell in this country. These investigators are in general agreement in regard to the abnormal mobility of the joint produced by division of the various ligaments. There is a difference of opinion, however, as to whether or not there is an increase in abduction of the tibia on the femur with complete section of the tibial collateral ligament. Brantigan and Voshell stated that this division produces no increase in abduction, while Palmer stated that there is a definite though limited increase in this abnormal mobility. A limited study in the authors' laboratories confirms the opinion of Palmer. The authors' findings in these studies of six knees are summarized in the following paragraphs.

Complete Division of the Tibial Collateral Ligament

In full extension, there is no lateral instability when the tibial collateral ligament alone is divided. In 5 to 15 degrees of flexion, abduction rocking does occur to a limited extent, — a gap of from three to six millimeters occurring between the medial tibial and medial femoral condyles. This is very slightly increased in greater degrees of flexion, but in no instances does it exceed ten millimeters.

There is no increase in anteroposterior sagittal displacement (drawer sign).

In flexion, medial and lateral rotations are increased. These are difficult to measure, but the arc of rotation in 90 degrees of flexion is increased approximately 15 degrees after division of the tibial collateral ligament.

Complete Division of the Anterior Cruciate Ligament

If all other ligaments are left intact and the anterior cruciate is severed, no abnormal lateral instability is found. The anterior drawer sign is increased by five to ten millimeters, and the knee may be moved into as much as twenty-five degrees of extension beyond a straight line. There is a slight increase of medial rotation of the femur on the tibia.

If, in addition to division of the anterior cruciate ligament, the tibial collateral ligament is stretched, the drawer sign is further increased. If the tibial collateral ligament is entirely severed, the drawer sign is maximal.

When this degree of drawer sign is present, indicating a complete tear of both the tibial collateral and anterior cruciate ligaments, abduction rocking is markedly increased. In full hyperextension without rotation, there is no abduction rocking. In a position of 180 degrees of extension, 10 to 15 degrees of rocking is found, and in 140 to 160 degrees of extension as much as 30 degrees of abduction rocking may be obtained.

MECHANISM OF INJURY OF THE LIGAMENTS

When the knee joint is subjected to a severe or abnormal force, it tends to subluxate. The capsule or one or more of the ligaments may be overstretched or completely ruptured.

Palmer describes four types of subluxating violence, which most frequently result in injuries to the ligaments.

Hyperextension: A blow on the anterior aspect of the extended leg forces the knee into hyperextension. If the force is sufficiently severe, the posterior capsule is stretched and weakened. A few of the posterior fibers of the posterior cruciate ligament may be frayed, and then the major injury, rupture of the anterior cruciate ligament, may follow, usually with avulsion of a fragment of bone from its tibial insertion (Fig. 11).

Abduction, Flexion, and Internal Rotation: This type of subluxating force is met with most frequently in football and in skiing injuries. The weight of the body is thrown inward, and the femur is rotated medially, while the foot is fixed by the weight of the body or by some obstruction. The most common injury resulting from this type of subluxating violence is: first, a stretching or partial tearing of the long superficial and direct deep fibers of the tibial collateral ligament; second, a rupture of the anterior cruciate ligament or the fraying of some of its fibers near the superior insertion, as it becomes stretched over the medially shifted medial border of the lateral femoral condyle. Some authorities feel that the posterior cruciate ligament is also frequently injured as a result of this type of violence. Such injuries are often associated with tears of the medial meniscus. A compression fracture of the lateral tibial condyle may also occur. When the injury results in a fracture, the ligaments are usually not severely damaged.

Adduction, External Rotation, and Flexion: Adduction injuries to the knee are not common, but are seen occasionally in football, motorcycle, and skiing accidents. The force is applied to the medial side of the leg near the knee joint, while the foot is fixed. A pure adduction subluxation injury may result from trauma to the extended knee. If the

FIG. 7

A common mechanism of injury,—forceful flexion, abduction, and internal rotation of the femur on the fixed leg. (*Redrawn from Palmer, p. 64, Fig. 13.*)

knee is flexed, the component of lateral rotation is also present. In this type of injury, the fibular collateral ligament is the first to rupture, followed shortly by the anterior cruciate ligament, and often by the tendon of the popliteus muscle. Since the common peroneal nerve is close to the head and neck of the fibula, it, too, may be torn in adduction injuries.

Sagittal Displacement: Forcible posterior tibial displacement with the knee flexed produces a sagittal subluxation injury. Obviously the posterior cruciate ligament must be torn. Clinically, it is usually avulsed from its tibial insertion with a small fragment of bone. If the force continues after this has occurred, the detached end, along with the piece of bone, is drawn through the posterior capsule into the joint. The rupture may also occur near the femoral insertion. Palmer emphasized the importance of recognizing a contusion hematoma on the anterior aspect of the upper leg as a diagnostic sign in such injuries.

In addition to the four common types of subluxation injuries just described, there are several others, such as hyperflexion, hyperrotation, and posterior sagittal displacement of the femur on the tibia, the effects of which have been studied on the cadaver, but whose clinical significance is probably slight. For the sake of brevity, a discussion of these uncommon mechanisms of injury is omitted.

Although the subluxations are described as occurring with direct trauma, indirect violence with the inertia of the patient's body as the important force, is a frequent if not the most common cause of the subluxation. An analysis of the kinetics and dynamics of the forces involved in injuries resulting from indirect trauma is beyond the scope of this paper. It is, however, safe to say that whatever the exact mechanism of injury may be in the majority of cases, the actual subluxating force will be found to correspond to one of the four main types described above.

INJURIES TO THE TIBIAL COLLATERAL LIGAMENT

The commonest position in which the knee joint is injured is one of abduction, flexion, and medial rotation. The first structure to offer passive resistance to forcible exaggeration of this position is the tibial collateral ligament. Injuries to this ligament, therefore,

occur more frequently than to any other supporting structure of the joint. The tearing may be partial or complete, and isolated or associated with other lesions.

The types of rupture are well described and illustrated by Palmer as follows: There may be rupture at the superior insertion with or without detachment of a bone fragment. In these two types, the synovial membrane is ruptured superiorly and the meniscus follows the articular surface of the tibia in rocking (Fig. 8*A* and *B*). In total rupture of the inferior attachment of the ligament, the synovial capsules may be torn inferiorly and the tail of the ligament may be sucked into the joint (Fig. 8*C*). In another type, the ligament may be detached from the meniscus, while the synovial capsule is usually torn superiorly, and the meniscus tends to follow the tibial articular surface (Fig. 8*D*). Other cases show dissociated rupture at the superior and inferior insertions, and the meniscus is entirely loosened from both the ligament and the synovial capsule (Fig. 8*E*). There may be overstretching, with the meniscus detached from the ligament, and rupture of the synovial membrane superiorly (Fig. 8*F*).

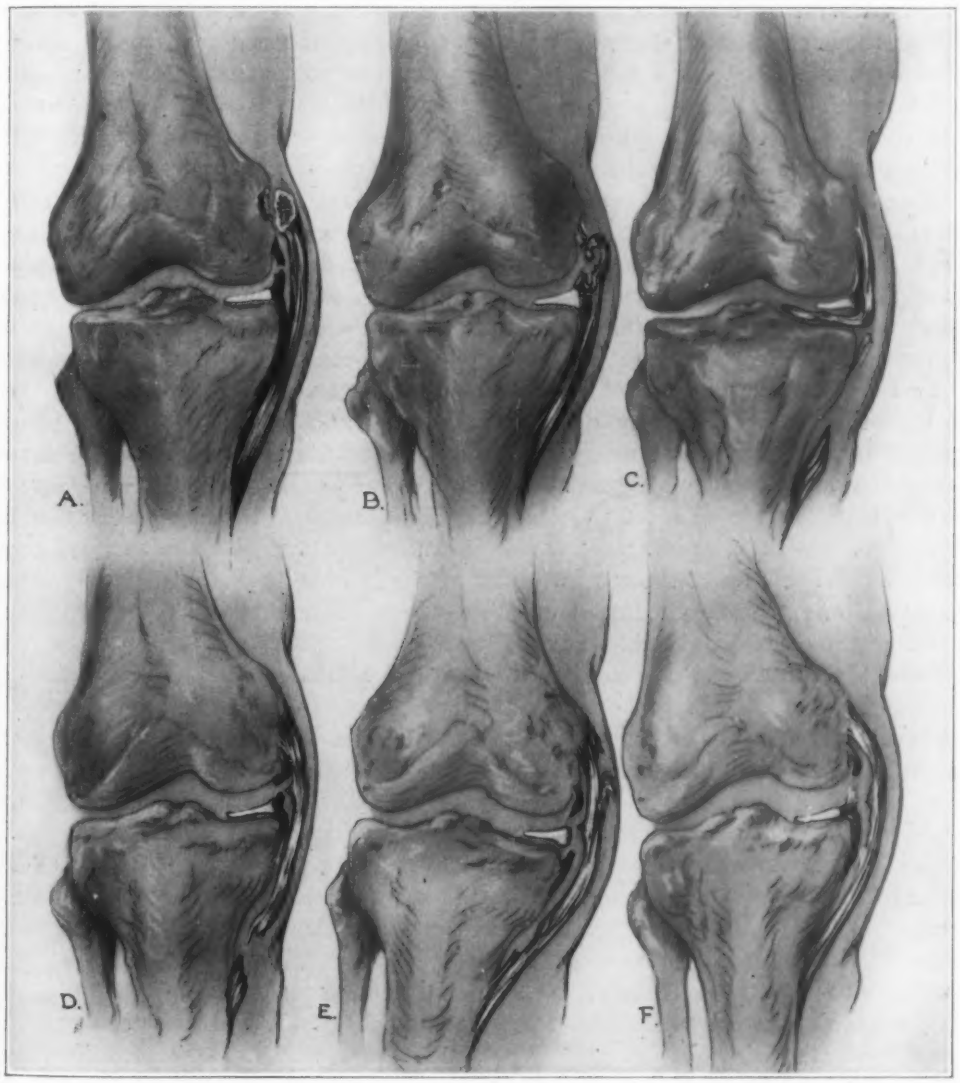

FIG. 8

The types of injury to the tibial collateral ligament. (*Redrawn from Palmer, pp. 82 and 83, Fig. 28.*)

Isolated injury of the tibial collateral ligament is a typical lesion with a well-defined clinical picture. Patients suffering from rupture of this ligament complain first of pain on the inner aspect of the joint. Soon after the injury, the pain is not so severe and the patient will often remain active. The pain, however, gradually increases until the disability becomes pronounced. Another typical complaint is inability fully to extend the knee. At first this position of flexion is purely voluntary to relieve discomfort, but later it is produced by involuntary spasm of the hamstring muscles. Walking may still be possible, but with only the toes touching the ground.

Significant clinical findings are tenderness over the inner surface of the knee directly at the site of injury, and active and passive resistance to complete extension of the joint. This inhibition of extension is a striking feature in the majority of cases, and is probably due to tonicity of the muscles which are functionally linked through the reflex arc with the injured ligament. Forced abduction at the knee causes pain which is referred to its inner surface. Another important finding which is present in a number of cases is the so-called abduction rocking. To obtain this evidence, Palmer advises firm support of the knee and leg by the arm and body of the examiner until the muscles are relaxed. A sudden abduction movement is then carried out; "the articular surfaces snap apart and, when the muscles start to function as a reflex action, spring together again with a click which is clearly discernible to the hand supporting the back of the knee". This sign is often difficult to elicit unless complete muscle relaxation can be secured. To obtain this relaxation, the patient is often examined under a general anaesthetic, preferably intravenous sodium pentothal. While the patient is under anaesthesia, the knees are held together by means of a linen bandage in a position of 15 to 20 degrees of flexion. This position of flexion is maintained by the support of a pillow underneath which an x-ray film is placed. The feet are then wedged apart by means of sand bags. Anteroposterior roentgenograms are then taken to ascertain if there is any difference in width of the joint spaces on their inner aspects. Increased separation of the joint surfaces may be found on the injured side in cases of complete rupture of the tibial collateral ligament.* Brantigan and Voshell state that their experiments on dissected specimens and fresh intact joints failed to show any increase of lateral movement when the collateral ligaments were divided. Palmer found as much as 20 degrees in the combined rocking of abduction and adduction in cases of isolated rupture of the tibial collateral ligament. Furthermore, he stated that, in hyperextension, the lateral rocking disappears as the articular surfaces are pressed together by the tension of the cruciate ligaments. If rocking of the joint is present in hyperextension, rupture of the anterior cruciate ligament should be suspected, in addition to a tear of the tibial collateral ligament.

While the authors' experience with this test is not sufficient to justify any final conclusions, they have found it to be positive in a number of cases of isolated rupture of the tibial collateral ligament, which was verified at operation. In such cases, there was minimal separation of the joint surfaces. In patients with wide separation of the joint surface, there was a rupture or stretching of the anterior cruciate ligament. The authors believe that the reason for the disagreement between the observers is due to the position in which the joint is held when attempting to elicit this sign. In complete extension, an intact anterior cruciate ligament prevents any degree of lateral play. If the knee is flexed as little as 5 degrees, the anterior cruciate ligament is relaxed sufficiently, so that, if the tibial collateral ligament is torn, an increased degree of lateral play or abduction rocking may be demonstrated. The authors regard the sign of abduction rocking as of great clinical importance, because, when positive, it indicates sufficient damage to the supporting ligaments to warrant operation.

Swelling, with bleeding into the joint, may or may not be present. A rupture of the ligament itself does not necessarily entail damage to the synovial membrane. If the

* This method of examination has also been described by Palmer.

synovial membrane is torn without rupture of the fibrous capsule, hemarthrosis may occur. On the other hand, tearing of the capsule and synovial membrane may lead to local hematoma as the blood escapes from the joint into the surrounding tissues. Hemarthrosis is often present in extensive damage to deep structures, such as the cruciate ligament, or when fracture is associated with the ligamentous injury. When present to any considerable degree, it is often painful, and, therefore, may prevent adequate examination. Furthermore, it may interfere with healing of damaged tissues and encourage the formation of adhesions. For these reasons, immediate and, when necessary, repeated aspirations are advocated in all cases in which the joint is distended. Aspiration is of great value in diagnosis and treatment.

DIFFERENTIAL DIAGNOSIS

The clinical picture just outlined is usually sufficient for a diagnosis of rupture of the tibial collateral ligament. The absence of a positive drawer sign would suggest that no concomitant lesions of the cruciate ligaments are present. On the other hand, a positive drawer sign with an extensive abduction rocking is evidence of injury to the cruciate ligaments, especially the anterior cruciate.

Limitation of extension may be due to reflex spasm, caused either by injury to the tibial collateral ligament, locking by a displaced meniscus, or distention of the joint with blood. Injection of the tender area of the injured ligament with novocain is, therefore, of value in diagnosis. If the reflex arc is blocked by anaesthesia, and there is no hemarthrosis or injury of the meniscus, the joint will assume a position of extension. In a distended knee, local anaesthesia may be combined with aspiration of the joint. Under anaesthesia, and with complete aspiration, a displaced meniscus will still resist extension,—an aid in diagnosis.

When relaxation cannot otherwise be obtained, general, spinal, or, preferably, intravenous anaesthesia is suggested to facilitate complete and thorough examination.

The following cases are typical of isolated injury to the tibial collateral ligament:

Case 1. L. M., twenty-nine years of age, was admitted to the Hospital on January 21, 1940. The patient had been injured while skiing, but could not recall the exact mechanism of the injury. When first

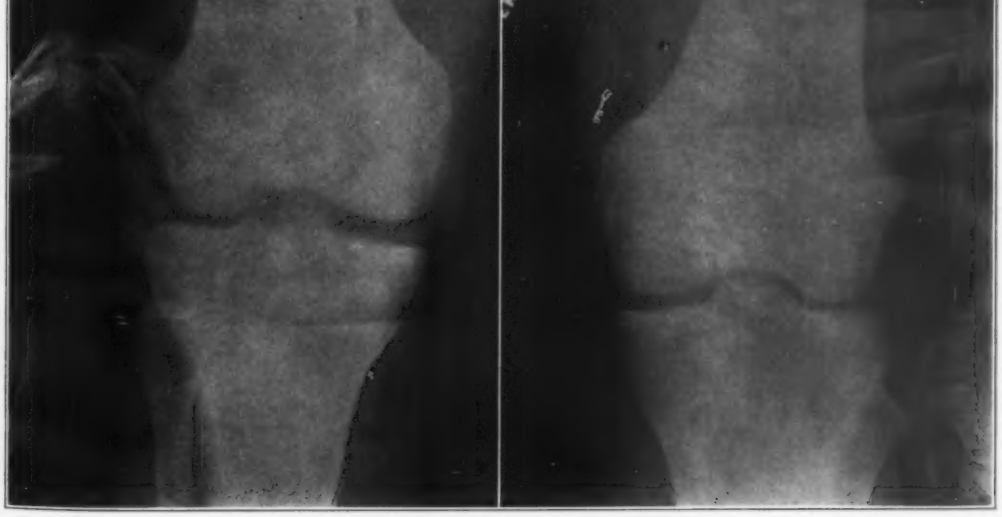

Fig. 9

Case 2. G. G. Increased width of the joint space on its inner aspect in injury to the tibial collateral ligament.

seen, the chief complaints were pain on the inner aspect of the knee, marked swelling, and inability to extend the joint.

Examination disclosed a large effusion into the joint. The knee was held in 15 degrees of flexion. The abduction-rocking sign was negative. The knee was aspirated, and the damaged tibial collateral ligament was injected with novocain. The knee could then be fully extended, but no lateral instability could be elicited by clinical examination or roentgenograms. The diagnosis was incomplete tear of the tibial collateral ligament.

A cast was applied, exercises of the quadriceps were soon started, and walking was later permitted with the weight deviated to the outside of the knee by raising the inner border of the heel.

Three months later the patient had a stable joint with excellent function.

This case well illustrates the treatment of incomplete lesions of the tibial collateral ligament in contrast to the following case in which the lesion was complete.

CASE 2. G. G., nineteen years of age, was admitted to the Hospital on February 17, 1937. The patient had injured her right knee while skiing. The history indicated an abduction injury, but details of the accident were vague.

Examination of the right knee disclosed tenderness in the region of the adductor tubercle of the femur, moderate swelling, and positive abduction rocking. Special roentgenograms, taken with the knees held in abduction, showed a moderate widening of the joint line on the medial aspect of the right knee (Fig. 9).

At the time of operation, a complete rupture of the femoral origin of the tibial collateral ligament was disclosed, together with a defect just below the adductor tubercle. There was no evidence of injury to the cruciate ligaments or meniscus. Repair of the rupture was effected by suture of the two portions of the ligament with silk.

On March 17, 1937, the patient was discharged from the Hospital.

The final result was complete restoration of function, and for the past three years the patient has been carrying on with athletic activity, including skiing.

INJURIES TO THE FIBULAR COLLATERAL LIGAMENT

Injury to the fibular collateral ligament is rare. It occurs when the knee is forced into a position of adduction, flexion, and rotation and may be associated with tearing of the lateral portion of the joint capsule. Other structures which may be stretched or ruptured are the common peroneal nerve, the popliteus tendon, the origin of the lateral head of the gastrocnemius, and the iliotibial band. The common site of injury is the in-

FIG. 10

Case 3. B. B. Increased width of the joint on its lateral aspect in rupture of the fibular collateral ligament, with avulsion fracture of the outer margin of the tibia.

ferior insertion of the ligament, the ligament taking with it a fragment of bone from the head of the fibula.

The important findings in the clinical picture are the history of violence to the knee, forcing it into adduction, with pain referred to the outer aspect of the joint, and local tenderness and swelling over its lateral aspect. Lateral adduction rocking can be elicited with the knee held in extension, and may be confirmed by roentgenograms of both knees held in exactly the same position.

The diagnosis should not be difficult in the absence of injury to other supportive ligaments of the joint. The drawer sign is negative and all findings are referable to an injury to the outer side of the joint. In associated trauma to the external popliteal nerve, sensory and motor changes will be apparent on examination of the foot and leg.

The following case is a good example of this type of injury:

CASE 3. B. B., sixteen years of age, was admitted to the Hospital on March 18, 1940. While running to the left in a football game, the patient had been hit directly from in front in the region of the left knee. There is no history of his early symptoms or treatment. He was sent to this Clinic by Dr. Harold Hitchcock, with a diagnosis of tear of the fibular collateral ligament.

Examination disclosed tenderness over the lateral side of the joint, swelling, and oedema. There was adduction rocking of the joint, and roentgenograms disclosed an increase in width of the joint space on its lateral side. A chip of bone had been torn from the lateral edge of the left tibia at the insertion of the capsular ligaments (Fig. 10).

An incision was made on the lateral aspect of the leg along the anterior border of the biceps femoris muscle, with exposure of the biceps tendon, the neck of the fibula, and the external popliteal nerve. The nerve was undamaged. The lateral ligament was torn at the junction of its distal and middle thirds, and a large fragment of bone and cartilage, measuring about two and one-half by two centimenters, could be seen beneath the ligament on motion of the knee. It could be fitted into a depression on the lateral tuberosity of the tibia. The lateral meniscus was removed. The fibular collateral ligament was reconstructed by utilizing part of the tendon of the biceps, and a segment of the tendon was dissected free, leaving it attached to the neck of the fibula. The proximal end was passed through a small drill hole in the lateral femoral condyle, and a plaster-of-Paris cast was applied, with the knee held in about 15 degrees of flexion and as much abduction as possible.

On February 2, 1941, the patient had a normally functioning joint and had resumed active athletic pursuits.

INJURIES TO THE CRUCIATE LIGAMENTS

Under this heading only isolated injuries to the cruciate ligaments will be considered. They are less common than isolated injuries to the collateral ligaments. Damage to the anterior cruciate ligament is usually caused by forcible hyperextension of the joint. A blow on the front of the upper end of the tibia, with the femur and foot fixed, frequently results in injury to the posterior cruciate ligament. These isolated injuries of the cruciate ligaments are generally of the sprain-fracture type, with a segment of bone torn loose from the upper surfaces of the tuberosities of the tibia (Figs. 11 and 12). The injury is often accompanied by hemorrhage, with pronounced distention of the joint. In the case of rupture of the posterior cruciate ligament, a hematoma in the popliteal space may dissect its way to the surface.

In a rupture of either cruciate ligament, the patient complains that the leg "crumples up and gives way" and that there is a feeling of complete insecurity when the knee moves into a position of flexion. The instability of the joint in the sagittal plane gives rise to the so-called drawer sign. This sign is elicited with the knee held in a position of right-angle flexion. If the anterior cruciate ligament has been torn, the tibia can be displaced forward on the femur, abnormally when compared to the amount on the normal side. If the posterior cruciate has been torn, the tibia can be displaced backward on the femur to an abnormal degree. The so-called anterior drawer sign, in cases of rupture of the anterior cruciate ligament, is often present only early after injury. Once the reflex tonus of the hamstring muscles has returned, this sign is frequently absent.

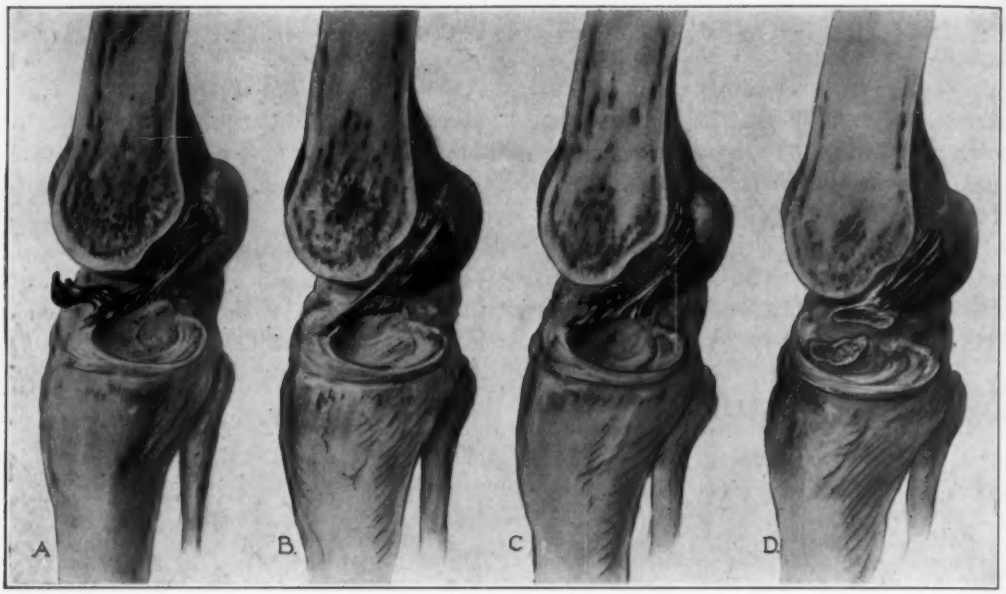

FIG. 11

The types of injury to the anterior cruciate ligament. (*Redrawn from Palmer, pp. 104 and 105, Fig. 43.*)

Suspected damage to either cruciate ligament calls for a careful history eliciting the mechanism of injury, and a thorough and complete examination. This examination often calls for repeated aspirations of the joint. A general anaesthetic may be given to obtain the complete relaxation of the hamstring muscles, which permits an adequate examination. Isolated injuries of the cruciate ligament are often sprain fractures, and, therefore, roentgenograms immediately after injury are helpful in diagnosis. In such cases, an operation to replace the fragment is often indicated.

The anatomical basis for the drawer sign has been demonstrated by Palmer in experiments on the cadaver. If the collateral ligaments are removed and the rest of the ligament apparatus is left intact, sagittal displacement is impossible in positions of flexion and extension. If the collateral ligaments and the posterior capsule are split, sagittal displacement is also impossible. If the cruciate ligaments are completely removed and the collateral are left intact, the joint is stable in the extended position. Increased hyperextension cannot be demonstrated. In the flexed position of 90 degrees, the femoral condyles can be shifted without rotation from ten to fifteen millimeters over the tibial surface. The lateral femoral condyle is, however, more mobile and can, if movement is combined with rotation, be shifted twice as far,—that is, about twenty-five millimeters. With stretching of the tibial collateral ligament to produce the abduction rocking of three millimeters, the sagittal displacement is more than doubled. When the ligament is loosened from its medial attach-

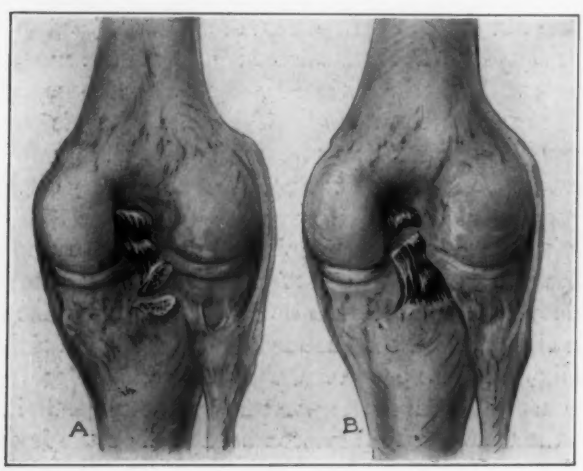

FIG. 12

The two types of injury to the posterior cruciate ligament. (*Redrawn from Palmer, p. 106, Fig. 44.*)

ment to the internal meniscus, the joint capsule, and the margin of the tibial condyle, the range of sagittal displacement is increased to forty-five millimeters, thus covering the whole breadth of the tibial condyle. The tibia can be luxated both anteriorly and posteriorly. Therefore, the drawer sign is increased by a stretched tibial collateral ligament, and will be maximal when the collateral ligament is torn free from its moorings to the tibia, the medial meniscus, and the capsule of the joint.

The following cases illustrate injuries to the anterior and posterior cruciate ligaments:

CASE 4. G. G., twelve years of age, was admitted to the Hospital on October 9, 1940. While playing, the patient had jumped from a sand bank and landed on her right foot with the knee partially flexed and medially rotated. Severe pain, swelling, and instability of the knee, with limitation of full extension immediately followed the accident.

Roentgenograms of the right knee on October 10 showed a fracture involving the medial tibial spine and the adjacent portion of the articular surface of the upper end of the tibia (Fig. 13). A positive anterior drawer sign was present, but no abduction rocking could be elicited.

Through a medial parapatellar incision, the fracture site was exposed. A piece of bone with its overlying cartilage had been avulsed from the intercondylar region of the upper surface of the tibia by the anterior cruciate ligament. With the knee in a position of slight flexion, the fragment was reduced and fixed by a square, stainless-steel nail. The limb was then placed in a plaster-of-Paris cast.

On December 4, 1940, the knee could be flexed to 90 degrees and extended to 170 degrees; and the patient walked without pain.

Four months later she had a stable knee with full range of motion and complained of slight aching only after walking for several miles.

CASE 5. F. G., thirty years of age, was injured on June 10, 1943. He had been driving an automobile when a head-on collision with another vehicle occurred. The impact threw him forward and his right knee struck against the dashboard. He was seen in the Emergency Hospital within two hours after the injury. His right knee was swollen and painful. There was also a contusion of his chest. He could not bear weight on the right leg.

Examination revealed marked hemarthrosis, a contusion over the anterior upper right tibia, and swelling and tenderness in the popliteal fossa. The posterior drawer sign was positive, while the anterior drawer sign was negative. There was no lateral instability.

Roentgenograms revealed a fragment of bone, five-tenths by one centimeter in size, lying just above the mid-portion of the posterior rim of the tibia (Fig. 14-A and 14-B). Because of the contusion of the patient's chest, the operation was delayed for several days. At the end of the fourth day, marked ecchymosis was present over the back of the knee.

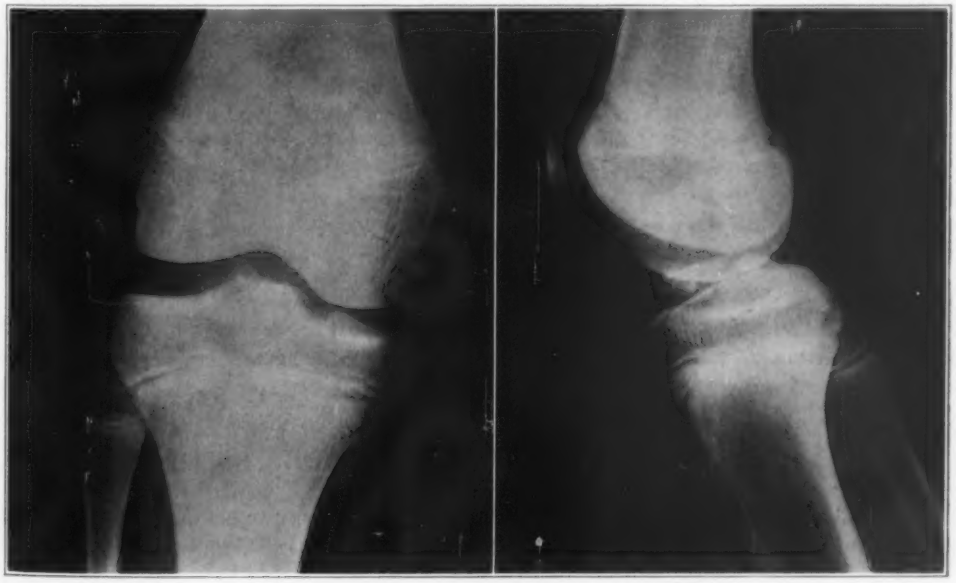

FIG. 13

Case 4. G. G. Injury to the anterior cruciate ligament with an avulsion of a fragment of bone from the tibia.

FIG. 14-A

FIG. 14-B

Case 5. F. G. June 10, 1943, showing injury to the posterior cruciate ligament with an avulsion of a fragment of bone from the tibia.

Operation June 15, 1943. With the patient in the prone position, the posterior portion of the knee was exposed through a mid-line popliteal incision. The posterior cutaneous nerve of the calf was identified and followed down to the posterior tibial nerve and popliteal artery and vein. The lateral head of the gastrocnemius was divided at its femoral origin and retracted medially with the vessels and nerves. The posterior capsule of the knee was exposed, and a fragment of bone one centimeter in diameter was found attached to the inferior portion of the posterior cruciate ligament. This fragment was pulled up through the capsule. With the knee in slight flexion, this loose bone fragment could be fitted exactly into a defect on the posterior rim of the tibia. The fragment was reduced and fixed by means of a small screw (Figs. 14-C and 14-D). After closure of the wound a long leg cast was applied with the knee in 20 degrees of flexion. Quadriceps exercises were begun on the second day. The cast was bivalved for active knee motion at the end of the third week. Protected weight-bearing was allowed at the end of the fifth week. The patient was last seen four months after operation, at which time he had no complaints; the knee was stable, with good muscle power and full range of motion.

COMBINED INJURIES

Severe trauma may cause injury to more than one ligament. Various combinations may occur, depending upon the direction and violence of the force causing the injury. Both cruciate ligaments may be ruptured by extreme hyperextension, or a blow from the inner side of the knee may rupture the fibular collateral and one or both of the cruciate ligaments. In addition to the ligamentous tears, there may be avulsion or compression fractures of the joint surfaces. Frequently a meniscus is torn or displaced.

In the authors' experience, the most common combined injury is that which results from forced abduction, flexion, and medial rotation of the femur on the tibia. This type of trauma usually causes not only a complete rupture of the tibial collateral ligament; but also, with further abduction, it results in stretching or tearing of the anterior cruciate over the medially displaced inner border of the lateral femoral condyle. Associated damage to the medial meniscus is frequently present also. It is in such cases that marked abduction

FIG. 14-C FIG. 14-D

June 21, 1943. Postoperative roentgenograms.

rocking and a positive drawer sign are found. Operation, with repair of the torn ligaments, is always indicated.

This triad of tibial collateral and anterior cruciate tearing, with injury to the medial meniscus, is the most frequent, the most important, and, if neglected, one of the most disabling of the combined ligamentous injuries to the knee.

The following case illustrates one of the common types of combined injuries.

CASE 6. D. S., forty-two years of age, was admitted to the Hospital on February 9, 1941. The patient was injured while skiing on February 7. While going down hill at high speed, the right ski had caught in the snow and she had pitched forward, falling to the left and forcing her right knee into flexion and abduction. Immediately following the accident, she had experienced severe pain and she could not move until both feet had been freed from the skis. Later she proceeded to the lodge on her skis, but she noted that any rotation, complete extension, or lateral bending caused intense pain in the back and inner aspect of her right knee. A diagnosis of complete rupture of the tibial collateral ligament and a tearing of the medial meniscus was made by the local physician. A plaster-of-Paris cast had been applied and she had been told that it should remain in place for eight weeks.

On February 9, two days after the accident, the authors' examination revealed a position of genu valgum, swelling, and tenderness over the inner aspect of the right knee near the level of the joint line. A marked degree of abduction rocking was elicited with severe pain. There was a pronounced anterior drawer sign. Roentgenograms disclosed an exaggerated widening of the joint space on the inner aspect of the right knee (Fig. 15).

An operation was performed under spinal anaesthesia on February 10. There was extensive laceration of the superficial or long part of the tibial collateral ligament and a tearing of its entire deep portion from the femoral condyle. The medial meniscus was highly movable, but it was not detached from the capsule. Its anterior horn was hemorrhagic. There was a tear through the greater part of the anterior cruciate ligament near its femoral insertion, with preservation of its posterior third.

FIG. 15

Case 6. D. S. Widening of the medial joint space in rupture of both the tibial collateral and anterior cruciate ligaments.

The tibial collateral ligament was repaired and reinforced with fascia. The torn portion of the anterior cruciate ligament was sutured to its intact posterior third. Immobilization was secured with a plaster cast. The patient has been observed over a period of two years, and has a useful and stable joint.

DISCUSSION

From a group of twenty-six cases of injuries to the ligaments of the knee joint, certain essential findings for diagnosis and the results secured from treatment have been recorded. The injuries occurred in all ages and were nearly equally divided between males and females. The common mechanisms of injury were abduction alone, and abduction combined with flexion and rotation. In cases of isolated injuries to the cruciate ligaments, the mechanism of injury has been one which displaces the femur either anteriorly or posteriorly on the tibia in the sagittal plane. The injuries were commonly caused by playing football, skiing, or resulted from an automobile accident. The principal symptoms, listed in order of their importance, were instability, pain, and swelling. Objectively, local tenderness, hemarthrosis, and abnormal mobility were of constant occurrence. Roentgenograms, taken with or without anaesthesia, were helpful in the diagnosis of doubtful cases, were confirmatory in some, and, in still others, revealed the extent of damage or degree of instability.

A review of these cases shows quite clearly the importance of early and exact diagnosis with immediate institution of the proper method of treatment. Where this principle was followed, the results were excellent. In the late, incompletely diagnosed cases, the results were unsatisfactory. In combined lesions of the tibial collateral and anterior cruciate ligaments, prompt and complete repair of the tibial collateral ligament alone gave satisfactory restoration of function. Abduction rocking, as elicited by examination and roentgenograms, was found in all cases of injuries to the tibial collateral ligament alone or with associated damage to the cruciate ligaments. The opening on the medial aspect of the joint was minimal in isolated injuries to the tibial collateral ligament. In the authors' cases, it was greatly increased in the combined injuries to the ligaments of the knee joint. When pronounced abduction rocking was present, the findings were complete rupture of the tibial collateral ligament, and often complete rupture of the anterior cruciate. In

some instances the anterior cruciate appeared to be intact, until further minute inspection revealed that it was slack and was probably the site of injury to the body of the ligament, without loss of continuity of the synovial covering. The question as to whether an isolated lesion of the tibial collateral ligament will show marked abduction rocking is a matter of academic interest. The test for abduction rocking is valuable to determine the necessity of operation. In the authors' experience, a definite opening of the medial aspect of the joint is a sufficient indication for operation. In wide separation, operation is absolutely essential, as indicated in combined lesions of the collateral and cruciate ligaments. In these cases, repair of the collateral ligaments is essential to secure a completely stable joint.

SUMMARY

1. Early and thorough examination is essential for exact diagnosis, which forms the basis for rational treatment in all injuries to the collateral and cruciate ligaments of the knee joint.

2. In addition to a careful history and examination, the authors advocate the use of certain tests which are helpful in diagnosis.

3. Abduction rocking to a moderate degree may indicate an isolated lesion of the tibial collateral ligament. Abduction rocking to a marked degree is indicative of combined injury to tibial collateral and anterior cruciate ligaments. Verification of abduction rocking is obtained by anteroposterior roentgenograms of both knees, held in abduction to show the relative degree of separation of the joint surfaces on their medial aspects. In the presence of muscle spasm, this test may require general anaesthesia. If this test is positive, an operation for repair of the injured ligament should be performed.

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THE RÔLE OF PENICILLIN IN THE MANAGEMENT OF INFECTION *

BY CAPTAIN JOSÉ M. FERRER, JR.

Medical Corps, Army of the United States

This paper, as the title indicates, is an attempt to convey the fact that penicillin has a definite place in the treatment of infection, but that it is not a so-called miracle drug in that it can cure any and all types of infection. Penicillin is of tremendous value in the treatment of certain infections—it is undoubtedly the most valuable single drug available to us today for this purpose—but its value is limited to those infections caused by penicillin-sensitive bacteria. It is an antibacterial agent of very high potency for those organisms which are susceptible to its action. Infections caused by organisms which are resistant to penicillin are unaffected by the administration of the drug. Thus, in prescribing penicillin, equal consideration must be given to the bacteriological and the clinical aspects of the infection. This prompts us to divide the pathogenic bacteria into two groups, penicillin-sensitive and penicillin-resistant. The following table is a compilation from several authors, and includes all the important penicillin-sensitive organisms, as well as many of the penicillin-resistant organisms.

Penicillin-Susceptible Organisms	*Penicillin-Resistant Organisms*
Pneumococcus	Hemophilus influenzae
Hemolytic streptococcus	Bacillus Friedländer
Streptococcus viridans	Escherichia coli
Staphylococci	Bacillus typhosus
Gonococcus	Bacillus proteus
Meningococcus	Bacillus dysenteriae
Corynebacterium diphtheriae	Bacillus paratyphosus
Bacillus subtilis	Bacillus pyocyaneus
Clostridium welchii	Vibrio cholerae
Vibrio septicus	Penicillia
Clostridium histolyticum	Monilia
Clostridium oedematiens	
Clostridium sordellii	
Treponema pallidum	
Spirochetes of relapsing fever	
Actinomyces	

The first criterion then for the use of penicillin is a bacteriological one—is the infecting organism penicillin-sensitive? Where time and the urgency of the situation permit, this should be finally determined by testing the activity of penicillin against the specific bacteria *in vitro* in the laboratory.

Once it has been decided to use penicillin, it is necessary to know its properties, methods of administration, dosage, and possible toxic reactions. The product as received from the manufacturers is a brownish-yellow powder, standardized not by weight or volume, but by unitage. This product contains between 50 and 70 per cent. of the sodium salt of penicillin and between 30 and 50 per cent. of impurities. It is freely soluble in distilled water or normal saline, and may be used clinically in either of these solutions. A solution of 5,000 units per cubic centimeter is recommended for systemic use, while 250 units per cubic centimeter has been found to be satisfactory for local application. All penicillin

* Presented at the Annual Meeting of The American Academy of Orthopaedic Surgeons in Chicago, Illinois, on January 25, 1944.

must be kept in an icebox at not above 5 degrees centigrade, and the solution should be used within twenty-four hours after it is made.

The systemic routes of administration of penicillin are limited to the intramuscular and intravenous. No other routes are satisfactory. A high initial concentration is obtained with the intravenous method, but this falls off rapidly; while the intramuscular method gives a more prolonged moderate concentration, but never reaches high levels.

The dosage of penicillin is still not uniformly established, but 120,000 units a day, given as 10,000 units intravenously every two hours, or 15,000 units intramuscularly every three hours, is a good base line. This basic dosage may be revised upward or downward as the situation demands. Streptococcus and pneumococcus infections without septicaemia respond well to 90,000 units a day. Gonorrhoea can be cured in a high percentage of cases with 50,000 units a day for one day. Staphylococcus infections require higher dosage, about 200,000 units a day being advisable, since some staphylococcus strains will develop resistance to penicillin, and an adequate dose should be given early. Septicaemia, gas gangrene, and other fulminating infections require very large amounts of the drug given intravenously, often as much as 400,000 units a day.

Untoward reactions to penicillin therapy are few and never serious. Urticaria is the most common one, and occurs in about 5 per cent. of cases. Transient appearance of red blood cells or casts in the urine and transient elevation of blood non-protein nitrogen are not uncommon manifestations. Thrombophlebitis, either at the site of repeated intravenous injections or in distant extremities, has been reported, but has been rare in our experience. No other unusual or toxic reactions have been noted in humans, although a recent paper by Hamre, Rake, McKee and MacPhillamy reported the death of guinea pigs from very large doses of penicillin, with areas of necrosis in the liver and at the site of injection.

The rôle of penicillin is limited by the susceptibility or resistance of the infecting organisms. Furthermore, it varies considerably in the different clinical types of infection. For the purposes of this paper, infections are divided into three clinical types: first, acute infection without death of tissue and hence without suppuration; second, acute infection with suppuration and death of tissue; and third, chronic infection, which invariably means death of tissue. In the second and third types, a foreign body may or may not be present. The rôle of penicillin is distinctly different in each of these three broad categories of infection. The following cases are presented to illustrate this difference.

The acute infections without suppuration are well illustrated by Case 1.

Case 1. A medical officer, thirty-two years old, developed a hemolytic streptococcus pharyngitis. Sulfonamide treatment was started, but the patient developed a sulfonamide rash. The infection progressed with the development of a cervical lymphadenitis. Fever rose to 104 degrees, and he had two chills. Blood cultures were negative, but a strongly hemolytic streptococcus was cultured from the throat. Penicillin was given intramuscularly, the total dose being 435,000 units in five days. The temperature fell rapidly to normal; the cervical lymphadenitis subsided; and the hemolytic streptococcus disappeared from the throat cultures.

This case illustrates the cure of this acute type of infection by the use of penicillin alone. Into this group fall the acute uncomplicated septicaemias, the cellulitides, and the early cases of acute hematogenous osteomyelitis, before changes are evident in the roentgenograms. These infections must be hit hard and promptly with large doses of penicillin from the beginning of treatment. Unfortunately, it has not been our experience to see any case of acute osteomyelitis early enough to warrant treatment with the drug alone, to the exclusion of surgery. However, personal communications indicate that five such cases have been treated successfully without surgery and without sequestration. Champ Lyons reports three cases so treated, two successfully, and one with the development of an extensive medullary abscess three months after penicillin therapy and apparent healing.

The next category is that of acute infection with suppuration and tissue necrosis.

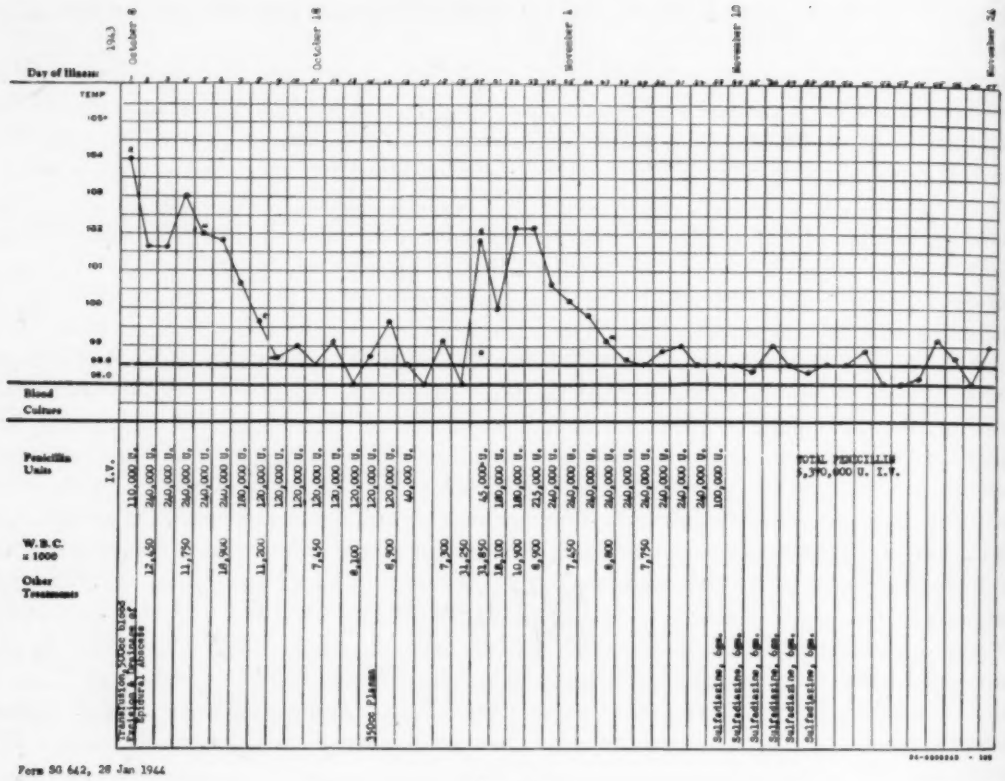

FIG. 1

Case 2. Temperature chart of patient with spinal epidural abscess. Penicillin therapy was started nine hours prior to surgery. At laminectomy a carbuncular infection was found in the epidural space.

CASE 2. A furuncle developed on the shoulder of a corporal, twenty-two years old. He squeezed it and it subsided. Ten days later he had chills, fever, abdominal distention, constipation, urinary retention, and weakness in both legs. Both knee jerks were absent, and both ankle jerks were hypertonic. Blood culture revealed a hemolytic staphylococcus aureus septicaemia. A diagnosis of spinal epidural abscess was made.

He received his first dose of penicillin thirty-six hours after the onset of symptoms, at which time his temperature was 102.5 degrees. In this type of case, penicillin is not the whole answer, and it would have been foolhardy indeed to have hoped that penicillin could cure this suppurating infection. Therefore, nine hours later a laminectomy of the ninth, tenth, eleventh, and twelfth thoracic and the first lumbar vertebrae was done. An extensive, tunnelling, carbuncular type of abscess was found in the epidural space. The pus was evacuated, and much of the infected necrotic tissue surrounding the spinal cord was removed by curettement.

The secondary rise in temperature was due to a urinary infection. The patient did well postoperatively, and his convalescence was complicated only by a urinary infection resulting from an indwelling catheter. This was controlled with some difficulty, and he made a complete and otherwise uneventful recovery. He received a total dose of 5,370,000 units of penicillin, given intravenously over a period of thirty days. Penicillin was also instilled locally into the wound through Carrel tubes.

In the type of infection illustrated by this case, penicillin and surgery play equal parts. The drug is of no real value without surgical drainage of the suppurating process, while surgery alone may fail to halt the spread of the infection. In the drainage of hematogenous osteomyelitis, we know that surgery, with or without the sulfonamides, will cure some cases, but that many cases will progress to the chronic stage with further necrosis of bone and sequestration. There have not been enough cases reported as yet of surgery plus penicillin in this late acute stage of osteomyelitis to determine whether fewer of these cases will go on to a chronic osteomyelitis.

The major portion of our experience has been in the field of chronic infection involving

bone. These cases have included septic gunshot fractures and chronic osteomyelitis, due either to infected compound fractures or to hematogenous infection. In these cases there is invariably death of tissue with suppuration, and there are frequently foreign bodies. Each one of these cases is a complicated individual problem. Penicillin alone is of no value; the drug must be used as a part of an integrated program, combining several forms of therapy. These chronic cases are not simply a problem of infection; they involve wound-healing, protein depletion, disturbed fluid balance, anaemia, hypovitaminosis, as well as the necessity for adequate surgery. Surgery, to be adequate in these cases, must include proper drainage of localized pus, removal of foreign bodies, revision of wounds where necessary, and excision of necrotic and devitalized tissue, especially bony sequestra. Lyons has stressed these points and has reported careful nutritional and other studies on such cases before, during, and after penicillin therapy. If penicillin is to speed recovery appreciably in these chronic cases, it can do so only by helping to prepare the patients for surgery earlier and to bring them to the operating table in better general condition, and by permitting more complete and radical surgery through a decrease in the hazard of postoperative flare-up or spread of infection.

FIG. 2

Case 3. Roentgenogram of patient with chronic osteomyelitis of head, neck, and upper third of femur.

The rôle of penicillin in this chronic type of infection can best be illustrated by the following case reports, some successes and some partial failures; the latter were due not to the failure of penicillin, but to the fact that too much was expected from the drug. A complicating feature in many of these cases was that the infection was frequently a mixed one, containing both penicillin-sensitive and penicillin-resistant organisms.

Cases 3 and 4 illustrate how penicillin permits complete surgery with a high margin of safety.

CASE 3. A soldier, twenty-nine years of age, was in a jeep accident in the Southwest Pacific theater. He sustained a severe, simple, comminuted fracture-dislocation of the upper end of the right femur. After several unsuccessful attempts at closed reduction, an open reduction with wire fixation was done. A wound infection developed, and it soon became evident that he had a severe osteomyelitis. The wound was widely opened for drainage, and he was evacuated to the United States. When he arrived in the Zone of the Interior, his general condition was extremely poor, and his hip was draining profuse amounts of foul pus, from which hemolytic staphylococcus aureus and proteus bacillus were cultured. Two sequestrectomies were done with the administration of sulfonamides, but each time the surgery was of necessity limited because of the patient's poor local and general condition. Penicillin was then given in association with plasma, whole blood, vitamins, and high-protein, high-caloric diet. The drainage from the wound

diminished markedly; the soft tissues in the infected leg became healthier; and the general physical and mental condition of the patient improved to a marked degree. All this brought the patient's general condition to a level that made it possible to safely perform a very complete sequestrectomy and revision of the wound.

There was no postoperative reaction, the patient's highest temperature being 100 degrees. It was subsequently necessary to do two more sequestrectomies, and both bone and soft-tissue healing are now progressing satisfactorily. In this case penicillin, in a total dosage of 5,000,000 units, given intravenously, was in all probability the straw that tipped the scales in the right direction, but, without the other therapy, the drug would have produced only temporary improvement.

CASE 4. A soldier, twenty-six years old, sustained a compound, comminuted fracture of the left elbow from a shattering blow in an automobile accident. At a hospital near the site of the accident a débridement was done, and the wound was left open. Sulfonamides were given. Ten days later he had a full-blown infection of the elbow and numerous fragments of completely detached bone. Fourteen days after the injury, an extensive removal of completely detached bone fragments and an open reduction and fixation with vitallium screws were done in the presence of this infection, from which hemolytic streptococcus and hemolytic staphylococcus aureus had been cultured. He was started on penicillin immediately after operation and convalesced well; his maximum postoperative temperature was 102 degrees. He received a total of 4,560,000 units of penicillin, intravenously, over a period of thirty-eight days.

His arm improved steadily; all wounds have now been healed for two months, and he has beginning bony ankylosis of the elbow. In this case, too, penicillin allowed early radical surgery, with an improved result and a shortened period of hospitalization.

It is felt that once completely adequate surgery has been done, most bones and wounds will heal as rapidly under sulfonamide therapy as under penicillin; however, penicillin is distinctly superior to the sulfonamides in permitting complete surgery earlier and with greater safety.

The following case illustrates too great optimism as to what penicillin will do.

FIG. 3-A

Case 4. Roentgenogram of compound infected fracture of lower end of humerus. Fourteen days after injury, reduction and fixation were accomplished in the presence of infection; the wound was left open.

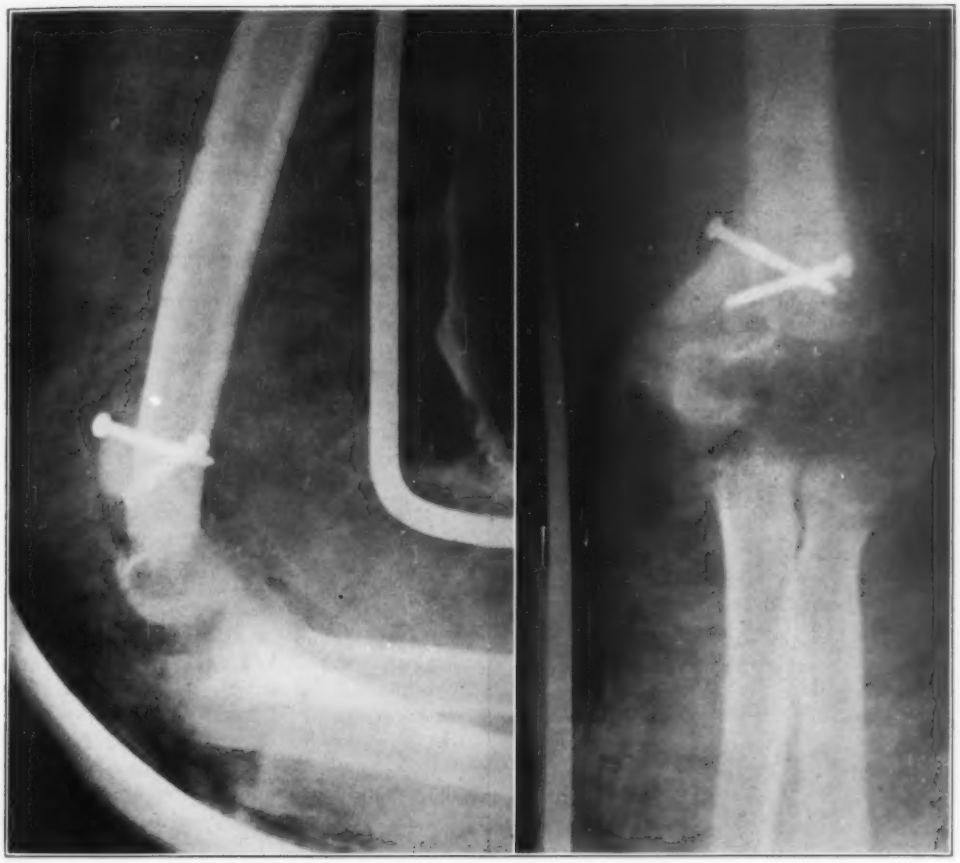

FIG. 3-B
Roentgenogram after reduction and fixation.

CASE 5. A soldier, twenty-five years of age, received a gunshot wound of the right shoulder in the Southwest Pacific theater. The missile shattered the clavicle and lacerated the brachial plexus. His wound was débrided, and later the clavicle was wired together. His wound was healed when he arrived in the Zone of the Interior; several months later the brachial plexus was repaired surgically, necessitating an osteotomy of the clavicle and internal fixation with wire. Eleven days after this operation, a wound infection developed with a pure culture of hemolytic staphylococcus aureus. The wound was opened and penicillin was started locally and intravenously. The infection came under control, and the wires in the clavicle were therefore not removed. The wound appeared to be healing, but forty-eight hours later flared up with another full-blown infection. The wound was again opened, and this time the wires were removed from the clavicle. However, the infection became chronic, and the wound continued to drain through a sinus which went down to the clavicle. The patient received penicillin throughout this period. Finally, there appeared definite roentgenographic evidence of sequestration. Another course of penicillin was started; the wound was opened, and the infected ends of the clavicle rongeured away. Bone and soft-part healing then progressed uneventfully, and the wound has now been healed for two months.

Fortunately, the repair of the brachial plexus was not affected by the infection, and steady improvement in the function of his hand and wrist has occurred. The total dosage of penicillin was 4,545,000 units, but some of this was not used to full advantage.

Two cases of infection in the presence of large metallic foreign bodies were of interest. These patients had bony defects of the skull, one secondary to gunshot wound and one secondary to falling masonry. Each wound had been healed over six months before a tantalum plate was inserted to cover the defect. Both wounds became infected postoperatively with a hemolytic staphylococcus aureus, but without evidence of osteomyelitis of the skull. Both abscesses were drained, and penicillin was given locally and intravenously. In the first case, a solid plate was inserted; in the second case, a plate with multiple per-

forations. In the first case, the plate had to be removed, because a large abscess developed between the plate and the dura. The second case progressed to complete healing without removal of the plate. Treatment was identical, and the size and location of the tantalum plates were comparable, except for the perforation of the plate in the second patient, which permitted free drainage of the space beneath the plate.

Penicillin could not have been expected to cure an undrained abscess, such as existed in the first case.

Two cases of osteomyelitis of the pelvis treated with penicillin were of interest.

CASE 6. An officer, thirty-one years old, had had roentgenographic evidence of a chronic osteomyelitis of the wing of the ilium for two years, but the wound had never broken down and drained externally. About three weeks before penicillin was started, a sinus broke open over his right hip and drained moderate amounts of pus, from which a hemolytic staphylococcus aureus was cultured. There was thickening and a sense of mass within the false pelvis. A total of 3,360,000 units of penicillin were given intravenously over a period of twenty-eight days.

FIG. 4-A

Case 5. Roentgenogram of clavicle with sequestration, following osteotomy and wiring to expose brachial plexus. Infection was re-alighted in previously infected wound. Despite penicillin therapy, sequestration resulted.

The staphylococcus disappeared from the cultures at the end of the second week of treatment; the intrapelvic mass disappeared; the sinus healed and has remained healed for the past four months. The bone, however, has not changed in appearance.

CASE 7. The second case of osteomyelitis of the pelvis was that of a soldier, thirty-seven years old, who had had incision and drainage of a furuncle on his shoulder. A hemolytic staphylococcus septicaemia developed, which was controlled with sulfadiazine. However, an osteomyelitis of the innominate bone and a lung abscess developed. Both these foci were drained surgically, and penicillin was given locally and intravenously. The innominate bone was drained externally, and over the iliac crest internally.

The patient is still in the hospital, but he is well on the road to recovery and his wounds are clean and healing.

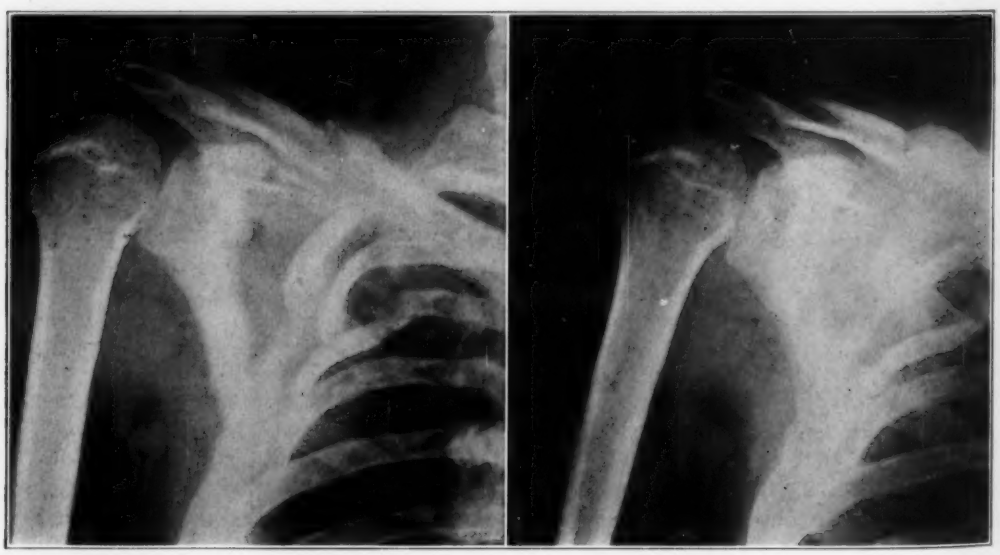

FIG. 4-B FIG. 4-C

Roentgenograms of healed clavicle after removal of the sequestrum. Drainage continued despite penicillin therapy until removal of the sequestrum.

FIG. 5-A FIG. 5-B

Case 6. Roentgenogram of patient with chronic osteomyelitis of ilium, pelvic granuloma, and recurrent drainage. Penicillin therapy without surgical intervention resulted in sterilization of drainage, disappearance of the pelvic mass, and sound healing.

FIG. 6-A

Case 7. Roentgenogram of subacute osteomyelitis of entire ilium, ischium, and pubis, September 28, 1943.

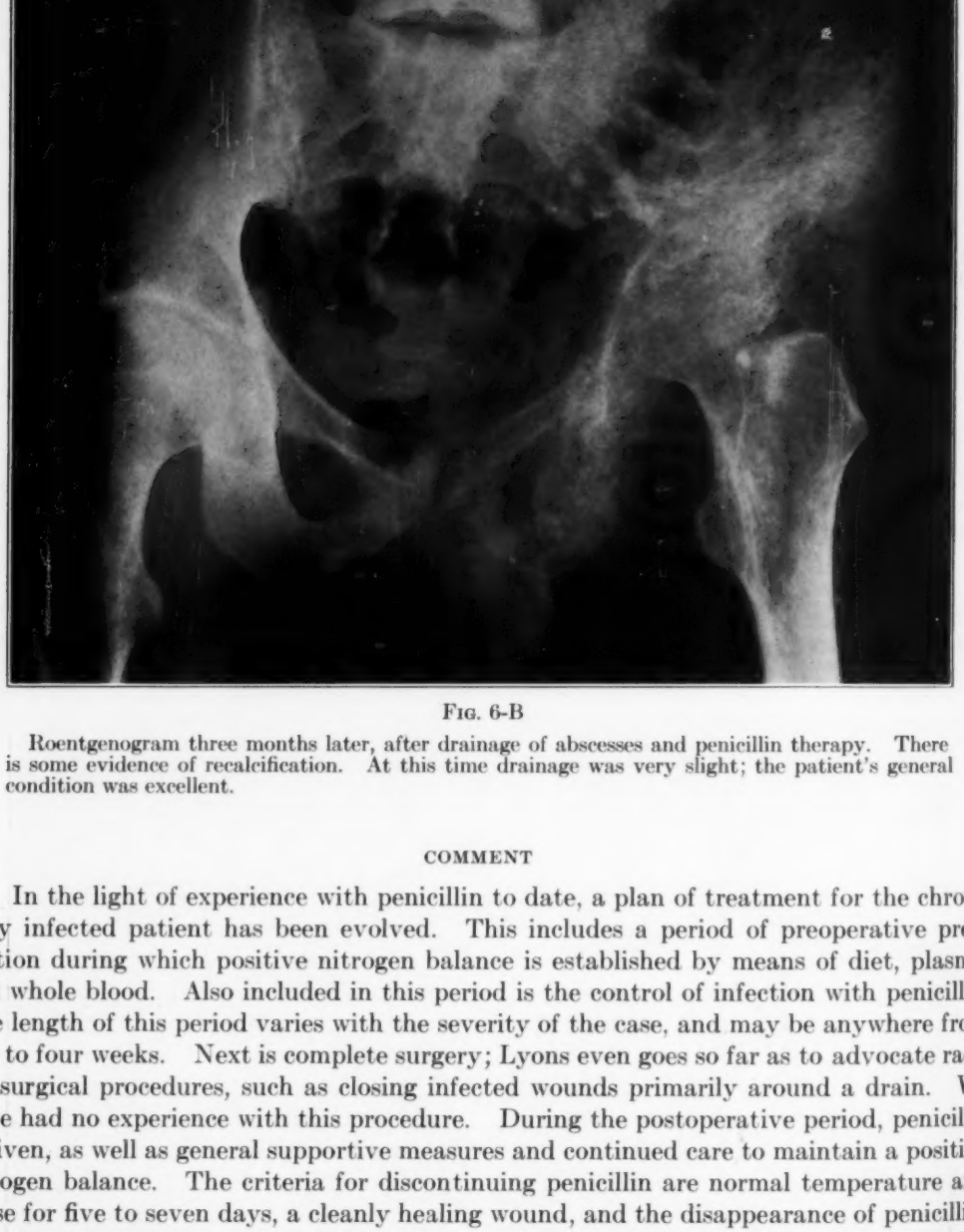

FIG. 6-B

Roentgenogram three months later, after drainage of abscesses and penicillin therapy. There is some evidence of recalcification. At this time drainage was very slight; the patient's general condition was excellent.

COMMENT

In the light of experience with penicillin to date, a plan of treatment for the chronically infected patient has been evolved. This includes a period of preoperative preparation during which positive nitrogen balance is established by means of diet, plasma, and whole blood. Also included in this period is the control of infection with penicillin. The length of this period varies with the severity of the case, and may be anywhere from one to four weeks. Next is complete surgery; Lyons even goes so far as to advocate radical surgical procedures, such as closing infected wounds primarily around a drain. We have had no experience with this procedure. During the postoperative period, penicillin is given, as well as general supportive measures and continued care to maintain a positive nitrogen balance. The criteria for discontinuing penicillin are normal temperature and pulse for five to seven days, a cleanly healing wound, and the disappearance of penicillin-sensitive organisms from the wound cultures. We believe that a similar program could be, and is being, carried out satisfactorily with the substitution of sulfonamides where penicillin is not available. However, it is our belief that penicillin has distinct advantages over the sulfonamides from the standpoints of time, effectiveness, and safety in the control of these infections.

CONCLUSIONS

1. Penicillin is a powerful antibacterial agent, but its rôle is a limited one. Pathogenic bacteria should be divided into two groups, penicillin-sensitive and penicillin-resistant.
2. Penicillin has no serious toxic manifestations in humans.

3. Penicillin alone is effective in acute infections without suppuration or death of tissue.

4. Penicillin and surgery are equally important in acute infections with suppuration and death of tissue.

5. Penicillin is but one of a number of therapeutic agents in the treatment of chronic infection with suppuration and death of tissue. It is effective in permitting adequate surgery earlier and with more safety.

6. The use of penicillin will not obviate the need for good surgery. Sequestra and foreign bodies, in particular, must still be removed from wounds before they will heal.

7. Penicillin is a more effective antibacterial agent than the sulfonamides against penicillin-sensitive organisms. Its action is not affected by the presence of pus, blood, or tissue autolysates.

8. The chief disadvantages of penicillin are the necessity for administering it by frequent intramuscular or intravenous injections, and its instability at room temperature.

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SURGICAL TREATMENT OF HALLUX VALGUS IN TROOPS IN TRAINING AT FORT JACKSON DURING THE YEAR OF 1942

BY LIEUTENANT COLONEL MATHER CLEVELAND, LIEUTENANT COLONEL LEON J. WILLIEN, AND MAJOR PATRICK C. DORAN

Medical Corps, Army of the United States

In civilian practice, the problem of hallux valgus or bunions is largely limited to women. These women submit to surgical treatment for two reasons,—pain and vanity. The soldier has no vanity and the cosmetic reason for operation does not exist. He seeks surgical relief solely because of pain. It is interesting to note that, in such a large infantry post as Fort Jackson, there were but twenty-five soldiers and officers during the year of 1942 who had hallux valgus or bunions, with symptoms severe enough to warrant surgery. The two officers were: a Lieutenant of the Air Force and a nurse. We of the Orthopaedic Section have undertaken an analysis of this small group to determine: (1) what type of operative procedure has been most useful; and (2) whether operative treatment has succeeded in returning a sufficient number of soldiers or officers to full duty to justify its use.

The rapid shifting of the soldier population of any Army post during war has made an end-result study difficult. The criterion of success or failure of operative treatment has been whether the soldier or officer has returned to full duty or has been reclassified for limited service. An operation of election, such as one for hallux valgus, cannot justify itself unless it results in full-duty status.

Of these twenty-five soldiers and officers operated upon for bunions, we know the end result in twenty-two, 88 per cent. In seven of these twenty-two, we learned the result under our observation at this post. The end result in each of the other fifteen cases was ascertained by letter, addressed to the Commanding Officer of the camp where the soldier or officer was then stationed, in which three simple facts were requested:

1. Was this soldier or officer able to resume full duty?
2. Was he reclassified for limited service?
3. Was he discharged from service on Certificate of Disability Discharge?

Space was left for remarks. The bare facts sufficed to give us the information.

Length of Service Prior to Operation

These twenty-five officers and soldiers had served in the Army an average of nine months. The shortest period of service was seven days, and the longest eight years and eight months. Most of these had served less than six months, and, for the most part, they were recent recruits. Four soldiers had barely arrived at the post, when they were admitted to the Hospital for treatment of bunions. The soldier with the shortest period of service prior to operation—that is, seven days—strangely enough was able to resume full duty and was on that status one year after operation.

Age

The average age of these officers and soldiers was twenty-eight, the ages ranging from twenty-one years to thirty-eight years and six months. The oldest soldier, after resuming full duty, was honorably discharged six months after operation, as being over age. In this instance our effort failed to add to the fighting strength of the Army.

Race

There were twenty-four white officers and enlisted men and one colored soldier in this group operated upon for bunions. This is almost the exact ratio of white to colored troops at this post.

Branch of Service

One-half of these soldiers were in the Infantry, while the rest were scattered among Field Artillery, Engineers, Air Force, and Medical Department, in that order.

Line-of-Duty Status

In only one instance was the surgical condition considered to have developed while the patient was in line of duty. This soldier, after twenty-one months of service, had had trouble with bunions for only six months. The remaining twenty-four officers or soldiers were in the classification of "Existed Prior to Induction or Enlistment".

TREATMENT

The surgical treatment of this small group of twenty-five soldiers and officers included forty operations, since in fifteen the condition was bilateral, and in ten unilateral. The types of operations performed were: (1) the Keller operation, (2) the McBride procedure, (3) simple excision of the exostosis, and (4) the Silver operation, in that order of frequency. These forty operations were performed by seven surgeons of the Orthopaedic Section.

Keller Procedure: This procedure was performed twenty-one times on twelve patients. The healing was uneventful in all, except in one instance where there was a severe trichophytosis treated for one month before the operation was performed. The skin healed, and the operative wound healed by first intention. The soldier left the hospital on the forty-second postoperative day. He returned one month later with an ulcer over the medial side of the toe. This invaded the deep tissues; an osteomyelitis of the phalanx

resulted; and a tiny sequestrum was extruded. Months later the wound healed satisfactorily, and this soldier was returned to limited service. These twelve patients on whom the Keller operation was performed remained in the hospital an average of forty-four days after operation. Three were on limited service prior to operation and one was recommended for this status by us. The others were returned to full duty.

McBride Procedure: There were twelve McBride operations performed on nine patients. A plaster-of-Paris dressing was applied for approximately two weeks in each instance. The wound healing was very unsatisfactory in four of these nine patients, and, in consequence, the average postoperative hospital stay was seventy-one days. All of these patients were on full duty before operation and were returned to that status.

Simple Excision of Exostosis: This procedure was performed on five feet (three patients). One of these had poor wound healing. The average postoperative period of hospitalization was fifty-four days. Two of these patients were returned to full duty, and one to limited service.

Silver Procedure: This was done on one patient with bilateral bunions. The wound healing was good, but the patient remained eighty-four days in the Hospital following operation. He was then returned to full duty.

The postoperative hospitalization in any operative procedure in the Army is prolonged beyond that required in civilian practice, because the soldier must be able to resume a given duty status when he leaves the Hospital.

END RESULTS

These are known on twenty-two of this group of twenty-five patients, 88 per cent. of the total. We consider the results satisfactory only if the soldier or officer has resumed full duty, and unsatisfactory if reclassification for limited service has been necessary. Perhaps most of those who have been placed on limited service following operation have been symptomatically benefited, but they have not been preserved to the Fighting Forces, and our first interest properly belongs to the group that can fight. Only five soldiers, one nurse, and one officer, 31.8 per cent. of the twenty-two with known end results, have remained on full-duty status; two of these had both feet operated upon. The average postoperative follow-up of these seven patients is a little more than one year. Fourteen of these soldiers, 63.6 per cent. of those having known end results, are on limited-service status, because of the condition for which the operation was performed. Three of these limited-service soldiers were on that status prior to operation, and two were recommended for it following operation. The other nine soldiers were returned to full duty, but were unable to stand the rigors of that status and were subsequently recommended for reclassification by their Unit surgeons. No soldier received a Certificate of Disability Discharge following operation because of the feet, although one soldier, thirty-eight years of age, resumed full duty for six months after operation, and was then honorably discharged from the Service, as being over age.

DISCUSSION

Certain factors apparently influence the duty status of these soldiers following operation for bunion:

Of the seven patients, including one nurse, who returned to and remained on full duty, five had only one foot involved and a single operation. This stands out as the most important single factor. These five soldiers were all in combat work, and had difficult assignments to perform. The nurse and other nurses subsequently operated upon have resumed full nursing duty, which, though arduous, does not compare with the work required of a combat soldier.

Five of the patients having McBride operations returned to full duty and only two of those having Keller operations; but, in this instance, the factor of unilateral and bilateral

operation must be considered. In those cases in which the end result is known, there were eight McBride operations and six of these were unilateral, while there were twelve Keller operations and only three were unilateral.

In hallus valgus the condition is apt to be bilateral, but one foot or the other usually shows greater deformity, and the patient is apt to center his complaints on that foot. In civilian practice, in such a case, it is usual to recommend operation on both feet, because the less deformed toe may subsequently become the site of symptoms, and the patient may have to submit to a second operative procedure. In applying this principle to the soldier we have made a definite mistake. The trauma of an operative procedure on both feet has literally left the soldier without a leg to stand on, and probably accounts in large part for the fact that so few have returned to full duty. In any operation on the soldier who is so dependent on his feet, the minimal surgery that can be done should be attempted and no more.

In comparing the various operative procedures, in spite of the fact that the Keller operation restored only two soldiers to full duty, it is our operation of choice for the following reasons:

The wound healing was, with one exception, excellent. The technique is simple, and the cosmetic and functional results are satisfactory The postoperative period of hospitalization is materially shorter than in any of the other procedures used in this small series. No immobilization of the foot is required, and the patient becomes ambulatory in a relatively short time.

The McBride procedure was employed next most frequently. A substantial number of these feet healed badly, perhaps due to too tight closure of the wound, which was a technical error. In any operation performed under tourniquet, the wound edges should be loosely approximated with interrupted sutures.

CONCLUSIONS

The operative treatment for bunions among soldiers in training restores too few to full duty to justify its recommendation. The exception to this is among Army nurses, where a high percentage of success may be expected. Fifty per cent. of the soldiers who had a single bunion operated upon have returned to full duty, but only 13.3 per cent. of those with bilateral bunions operated upon have returned to full duty.

NOTE.—Since the completion of this study, the limited-service status has been eliminated. We feel that very few of these fourteen soldiers who have been operated upon for bunions and returned to limited service will fail to meet the minimum standards for induction as prescribed by Mobilization Regulations 1-9. They may present a problem in reassignment.

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THE PRINCIPLES OF AMPUTATIONS OF THE FINGERS AND HAND *

BY MAJOR DONALD B. SLOCUM AND CAPTAIN DONALD R. PRATT

Medical Corps, Army of the United States

The hand is a functional and cosmetic unit. Orthopaedic and industrial surgeons have long appreciated the importance of the hand and the integrity of its parts. During time of war, the volume of injuries is tremendously increased, and new and complicated problems are constantly brought to the attention of the surgeon. The literature has presented meager information concerning the objectives of preserving and rehabilitating the injured hand. For the most part, it has dealt with generalizations on the early care of the traumatic hand, with an occasional reference to unusual plastic procedures of limited applicability.

The present discussion concerns itself with the fundamental principles of functional rehabilitation of the hand. The goal of treatment—conservative, surgical, and post-operative—is to obtain the maximum improvement in function and appearance with a minimum of disability, hospitalization, and compensability. Before any reconstructive procedure is undertaken, a careful evaluation of the patient must be made, for, without cooperation and a desire for rehabilitation on his part, the objectives cannot be attained. In every instance, the problem should be explained in detail to the patient. He should be made to understand the plan of treatment, the value and importance of his desire to obtain the greatest functional use of the hand, and his prospects for improvement, with emphasis on the value of each degree of return of function.

The cosmetic appearance of the hand should never be overlooked. Many persons, particularly women, are extremely sensitive about any hand deformity, and in some instances this may lead to the development of a psychosis. It is a fundamental rule of hand surgery to preserve as normal an appearance as possible. Fortunately this usually bears a reciprocal relation to the functional use of the hand.

Since the primary objective is to obtain the maximum use of the hand, each integral part, and the rôle it plays in function, must be considered. The fundamental units of function are grasp, pinch, and hook. Of these, grasp is the most important.

Grasp may be defined as the combined action of the fingers against the opposed thumb and the palm of the hand. The consummation of grasp is grip. The extension and spread of the fingers in preparation for grasp are dependent upon the combined action of the extensor and intrinsic muscles. The closing of the hand itself depends upon the long flexors and the lumbricales. The thumb must be lifted away from the side of the hand and drawn over the center of the palm. This action is dependent upon the ability of the abductor pollicis to lift the thumb away from the hand, the opponens and adductor pollicis to swing the thumb over the center of the palm, and the adductor pollicis and flexor pollicis longus to consummate the forceful flexion of the thumb against the fingers. The digits must have adequate length, normal joint motion, and strong pressure action. The breadth of the palm affords a wide base for stability and balance.

Pinch may be defined as the apposition of the tip of the thumb against the pads of the opposing fingers. Holding a pencil, a piece of paper, or a dish are familiar examples of this action. It requires the same thumb elements that are used in grasping. The action of a finger is dependent upon three things: intrinsic muscles which rotate and flex the finger at the metacarpophalangeal joint, the long flexor muscles, and normal motion of the joints. The web space between the thumb and finger must be wide, deep, and freely movable. *Multiple pinch* consists of bringing several fingers against the tip of the thumb,

* Presented to the Surgical Staff, Torney General Hospital, Palm Springs, California, August 16, 1943.

as in picking up a small object such as a nut or screw. In this latter action, the palmar arch (metacarpal arch) must be intact. This arch is formed by the metacarpal heads as the ring and little fingers swing radially to the thumb, and is dependent upon the mobility of these two at the carpometacarpal joints.

Hook action is exactly what the word implies. The fingers are flexed, so that their pads lie parallel and slightly away from the palm. This is a pure finger movement, entailing the use of the long flexor muscles. Under pathological conditions in which one or more of the fingers is fixed in the flexed position, hook action may still be accomplished, although other motions of the hands may be impaired.

INDICATIONS FOR AMPUTATION

There is only one indication where amputation is mandatory,—that is, loss of blood supply. This may be the result of injury or of peripheral vascular disease with local gangrene. In this instance, and in this instance alone, the loss of the part may be routinely predicted.

Other indications for amputation are:

1. In the acute traumatic hand:
   a. When a severe compound fracture involves a joint in which such irreparable damage has been incurred that, when healed, the joint will be completely or partially ankylosed. Such a fracture is difficult to control; the surrounding soft tissues are macerated; infection is present or imminent; and it is self-evident that the finger or a portion of the hand so injured will serve no useful function and should be sacrificed.
   b. When two or more structures are involved, and the surgeon is able to predict with a fair degree of certainty that the digit or portion of the hand will be functionless. For example, loss of skin, together with injury of the underlying tendon; loss of skin associated with a fracture, which in itself would not indicate amputation; severance of tendons in addition to severance of the principal digital nerves, *et cetera*.
2. In the infected hand:
   a. Uncontrolled infection of hematogenous origin or by wound contamination.
   b. Controlled infection in which the end result will be loss of function. The purpose of amputation in such cases is to shorten the convalescent period.
3. In tumors:
   a. Malignant.
   b. Benign, in which the removal of the growth would destroy function.
4. In cases of deformity:
   This includes all deformities in which function of the hand would be improved by removal of the part. For example, stiff, straight, useless fingers not closing into the palm of the hand, and marked flexion contractures without reconstructive possibilities. These conditions are most commonly the result of posttraumatic or postinfectious ankylosis or contracture, and pernicious surgical and traumatic scars.

In contradistinction, amputation is not indicated in the loss of only one structure, for severance of a tendon may be repaired, division or partial loss of a nerve may be repaired by suture, fractures may be reduced, and loss of skin replaced. With adequate care, these conditions may be treated with the anticipation of partial or complete restoration of function.

In cases where reconstruction surgery, with its resulting loss of time on the job and its hospitalization, imposes too great a financial burden, the surgeon may often be justified in amputating, where otherwise he would not be. Likewise, under stress of war, in order to return a man to duty in a shorter time, it is often found advisable to amputate a part of an extremity which would otherwise be treated conservatively.

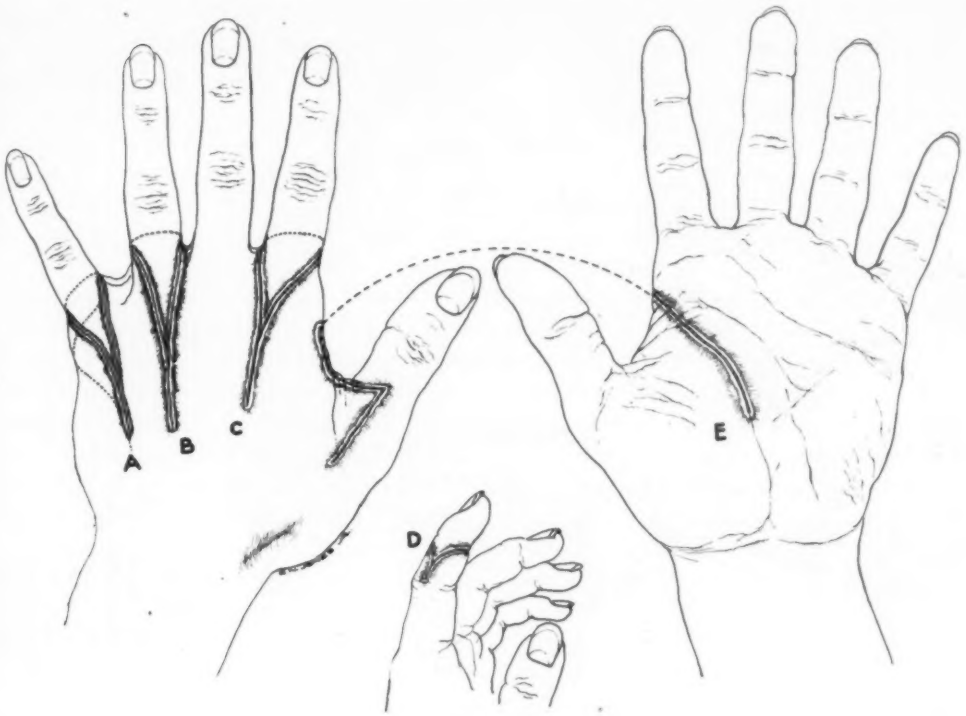

FIG. 1

Metacarpal amputation incisions. Incision *A* places the scar on the dorsum of the hand, and pads the ulnar aspect of the hand with tough palmar skin. The proximal dotted line shows the incision when performed at a higher level.

Incision *B* is used for the third and fourth metacarpal bones.

Incision *C* illustrates index-finger metacarpal amputation. This incision parallels the ulnar aspect of the second metacarpal, leaving the web between the thumb and middle finger free from contracting scar.

Incision *D* depicts the flaps in finger amputation. The palmar flap is slightly longer than the dorsal flap, so that the end of the bone is padded with palmar skin. The longitudinal portion of the incision falls over the mid-portion of the bone, rather than the mid-portion of the finger, which is slightly anterior.

Incision *E* demonstrates the incision for Z-plasty for widening the web space. The area adjacent to the angle on the dorsum of the thumb frequently requires a split-thickness skin graft, after transposition of the flap, to ensure maximum breadth of the web.

GENERAL CONSIDERATIONS

If an ideal amputation stump is to be obtained, specific attention must be given to each structure,—skin, tendons, nerves, blood vessels, periosteum, and bone.

An adequate skin covering with good sensation is a basic requirement for an ideal stump. Since the ends of the fingers and thumb must withstand constant trauma, the tough palmar skin makes a more satisfactory covering for the end of the bone than does the tender dorsal skin. For this reason, a long palmar and a short dorsal skin flap are used, so that the suture line falls posteriorly. The skin flaps must be sufficiently long to cover the end of the bone without tension. The best procedure is to place the finger in flexion when the dorsal flap is cut, and in extension when the palmar flap is made. Only too frequently the skin is cut too short, leaving it taut. This will inevitably result in limitation of motion by its restricting action. In some instances where the skin is drawn tightly over the bone end, the blood supply of the flap is sufficiently impaired to cause a local slough. Moreover, if the suture line is under tension, the scar may become wide, tender, and painful. When the flaps are inadequate, the bone must always be shortened to accommodate them, or supplemental skin must be utilized.

"Dog ears" at the lateral borders of the suture line can be avoided by a V plastic incision, or, in healed cases, by an elliptical incision which removes the redundant tissue.

FIG. 2

Types of hand amputation

A: Amputation proximal to the proximal interphalangeal joint of the index finger eliminates pinch and hook. By increasing the breadth of the hand it aids grasp, but frequently forms an impediment in the web.

B: Amputation at this level still leaves an obstacle in the web and does not add to grasp, because of the instability accompanying loss of the transverse metacarpal ligament.

B': The correct method of amputation of the index metacarpal.

C: Amputation proximal to the metacarpal head in the third or fourth metacarpals allows marked rotation deformity of the adjacent fingers. (*Continued on page 539.*)

FIG. 2. (*Continued from page 538*)

D: Excision of the third or fourth metacarpal allows the collapse of the metacarpal heads and prevents excessive rotation deformity, although it narrows the palm.
E: All possible length should be saved in the thumb.
F: In amputation of the index and middle fingers together at or distal to the metacarpophalangeal joints, all possible length should be saved to maintain the breadth of the palm for grasp.
G: In amputation of the index and middle metacarpals proximal to their heads, section of the bones should be carried out through the metacarpal bases to give an ideal web between the thumb and ring finger. Occasionally amputation will be necessary through the carpometacarpal joint to effect skin closure.
H: In amputation of the fifth metacarpal, all possible length should be saved.
I: In amputation of the fourth and fifth metacarpals, all possible length should be saved.

In the freshly injured hand, there may be found areas from which the skin has been torn away. It is essential that such an area be c ered by flaps of skin or skin graft immediately, as a portion thus exposed for any lengt f time will become infected and form scar tissue which will impair its functional use, sometimes irreparably.

The treatment of tendons is a simple but important element in finger amputation. It must be remembered that each phalanx has its individual motor supply. When the fingers are in the neutral anatomical position of 180 degrees, the distal phalanx is extended by the intrinsic muscles and flexed by the flexor profundus; the middle phalanx is extended by the intrinsic muscles and flexed by the flexor sublimus; and the proximal phalanx is extended by the common extensor muscle and flexed by the lumbricales. When the fingers lie in flexion beyond the neutral 180 degrees, though the flexor muscles involved in motion of the distal and middle phalanges remain the same, the intrinsic muscles, which otherwise extend them alone, now are reenforced by small slips from the common extensor. Since each unit of the digit has an individual motor supply, it is entirely unnecessary to suture the tendons which function beyond the site of amputation. Though such a procedure is often done with the intent of adding power or ensuring motion to the proximal joints, it accomplishes nothing, and may be definitely detrimental to function, since it is frequently the basis of flexion or extension contractures. The effect of these contractures on the normal function of the hand may readily be demonstrated by the following simple manoeuvre: An extension contracture may be simulated by forcibly holding the ring finger in hyperextension and trying to make a fist. It will be noticed immediately that the fingers cannot be fully closed into the palm. Then one may hold the ring finger in acute flexion, and attempt to open the hand. It will be seen that normal extension of the fingers will be greatly hampered. In dealing with tendons, the extensors are simply cut and allowed to retract. On the other hand, the flexor tendons must be sectioned in such a manner that the severed end will retract above the level of the transverse carpal ligament at the wrist, so that it will not form adhesions to adjacent tendons and soft tissues. This is more likely to happen when there is no peritenon (that is, no mucous sheath), and is particularly true of the flexor profundus tendons of other fingers. It should, therefore, be emphasized again that the tendon should be severed so it will lie above the transverse carpal ligament. This can usually be done by applying strong traction on the tendon, with the wrist in the flexed position when the section is made. To ensure that this has been accomplished, the portion of the tendon which has been removed is placed with one end at the incision and the other end over the wrist. In some instances it will be necessary to make a separate transverse incision at the level of the wrist for the removal of the tendon.

There are certain technical niceties in the treatment of the bone which will improve the end result. The bone should always be divided by a Gigli or key-hole saw, and the end of the bone should be rounded and smoothed with a file. The use of a rongeur, due to the nutcracker action of its jaws, usually causes a bursting type of fracture, extending the length of the bone and into the joint. This often results in excessive callus formation near the amputation site, and frequently a traumatic arthritis of the proximal joint. If infection develops, as it inevitably does in open amputation and occasionally in closed, it may track back through the fracture line into the joint and cause a septic arthritis. Although

amputation through the joint would not be satisfactory in other parts of the body, it is quite acceptable when dealing with the fingers or thumb, because the width of the condyle is not disfiguring and does not impair function as it would in the case of a limb, where a prosthesis would be worn. The articular cartilage should be removed from the bone end. Its presence may lead to a painful stump by causing bursal formation or hypertrophic overgrowth. Infection, should it develop, is much more difficult to control in the presence of chondral remnants. The bone ends should routinely be smoothed with a file to eliminate any projecting spurs that may remain. The periosteum is simply severed near the bone end, so that no loose ends are apparent.

The significant digital nerves lie in the palmar lateral aspects of the fingers and thumb. They should be carefully isolated fro their beds, crushed immediately proximal to the point where they will be severed, and ied with a fine suture of triple 0 (000) catgut or silk, or No. 38 stainless-steel or tantalum wire.

There is some difference of opinion regarding the advisability of injecting digital nerves with alcohol. If this procedure is used, a mosquito forceps should be placed about four millimeters above the tie, and the nerve should be injected with absolute alcohol between the tie and the clamp. The application of the forceps is necessary to prevent the spread of the alcohol, which might result in numbness of the proximal portion of the finger. Should the alcohol spread as far as the upper portion of the web where the nerve divides, with one branch passing to the adjacent finger, the result might be anaesthesia of this digit also. Occasionally a neuritis will occur from the injection of the alcohol, if it is not localized. During the injection, a moist sponge should be placed so as to protect the neighboring tissues from chemical necrosis.

The nerve should then be severed just distal to the tie and the area should be washed with saline. The nerve bed is next spread with a fine mosquito forceps and the nerve is tucked proximally into the deeper tissues of the finger or web, away from pressure areas and scar. If a neuroma should develop, it would then be out of the way and not likely to become symptomatic. The suggestion has been made to drill a hole into the adjacent bone and tuck the nerve end into it, on the basis that a neuroma, if formed, would be away from a pressure area. This is not advisable in the fingers, because constant motion acting on a fixed nerve ending will frequently result in a traction or irritation neuritis.

Blood vessels are simply cut and tied in the usual manner.

The formation of keloid at the suture line, painful adhesions of skin to bone, extensive scar tissue, poorly padded stump, poorly vascularized scar, tenderness due to latent infection, persistent sinuses due to infection, sequestra, or foreign bodies are complications which may usually be avoided, if care is taken with each phase of the amputation.

Finger Amputations

In amputations of the fingers, it is of prime importance to maintain as much as possible of the length, mobility, and muscle strength of the digits. In injuries of the finger tips, the restoration of length and a well-cushioned tactile pad is essential. A wide avascular scar covering the finger tip is undesirable, because of its almost constant association with pain, tenderness, and tissue breakdown. To prevent this, skin must be supplied either by shortening the finger, to allow the skin to approximate, or, better still, by applying a full-thickness skin graft or skin flap. The index and middle fingers are the most important in all functions, being stronger and more stable than the ring and little fingers, because of their relative fixation at the carpometacarpal articulations and their relative proximity to the thumb. The ring and little fingers have a wide range of motion at this articulation, which is necessary for the formation of the metacarpal arch. The chief value of the palm is its breadth, contributing largely to the stability of grasp and grip. As an example, in the use of a hammer, the fingers force the handle into the full width of the palm, resulting in a firm, stable grasp. Consequently, any decrease in the breadth of the palm will proportionally lessen the stability of grasp.

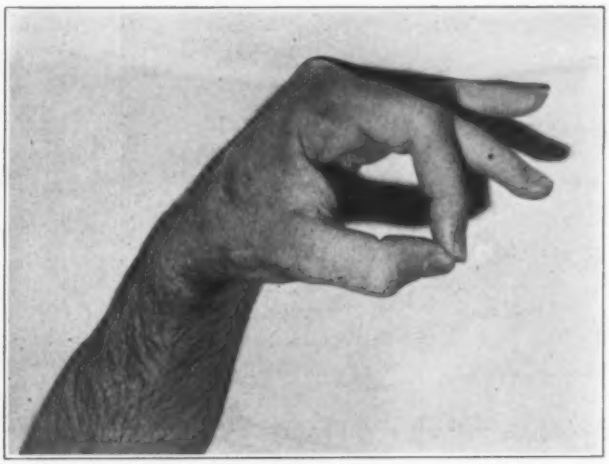

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FIG. 3-A FIG. 3-B

Amputation of the index metacarpal

Fig. 3-A: Prominent bone end is shown in an amputation through the index metacarpal just proximal to the head.

Fig. 3-B: Excellent functional and cosmetic result in amputation through the base of the index metacarpal.

The index finger is of greater functional importance than any other finger, because of its strength, position, stabilizing action in grasping, and pivot action during pinching. The length of the finger is of obvious importance in the spread of the fingers for a wide grasp, such as picking up a basketball, and in forming a large perfect O with the opposing thumb in pinch. In injuries of the tip of this finger more than of any other, a good reconstruction of the pad is vital. Amputation of the distal phalanx impairs pinching to a moderate degree; amputation through the middle phalanx impairs it materially; and amputation through the proximal phalanx causes pinching with the index finger to disappear; moreover the remaining stump is a decided detriment to the function of pinch, which must now be consummated with the middle finger. In this obstructive position in the midst of the web between the thumb and middle finger (Fig. 2*A*), the stump is subject to frequent bruising and is obviously in the way. At this point it must be decided which function is more important to the person being treated, that of grasp or that of pinch. In the case of laborers or those to whom the loss of fine movements is unimportant, the stump should be left at this level, thus maintaining the breadth and stability of the palm, which is so important a contributing factor in the grosser functions of grasp and hook. However, it will be found that, in some instances, it will be necessary to remove the stump because of the excessive awkwardness and associated bruising and pain. This does not apply, however, where complete relief is afforded by local minor surgery,—such as removal of neuroma, repair of a scar, or reamputation distal to the level of the metacarpal head.

On the other side of the picture is the man whose occupation demands fine skill in which no impediment can be tolerated, and the person who demands a fine cosmetic result (Fig. 3-B). In order to obtain the maximum of agility and fine movement and to improve the cosmetic appearance of the hand, a partial resection of the metacarpal bone should be done. This should be carried out through the base of the metacarpal (Fig. 2*B'*). Disarticulation at the carpometacarpal joint has the disadvantage of opening into the wrist joint and leaving an exposed cartilaginous surface. If the metacarpal is resected immediately behind the head or in the mid-shaft, the bone end still projecting under the skin in the web will remain tender and painful (Figs. 2*B* and 3-A). Moreover, with the loss of the stabilizing action of the transverse metacarpal ligament which binds the index metacarpal to that of the middle finger at the metacarpal heads, the remaining bone no longer

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FIG. 4-A

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FIG. 4-B

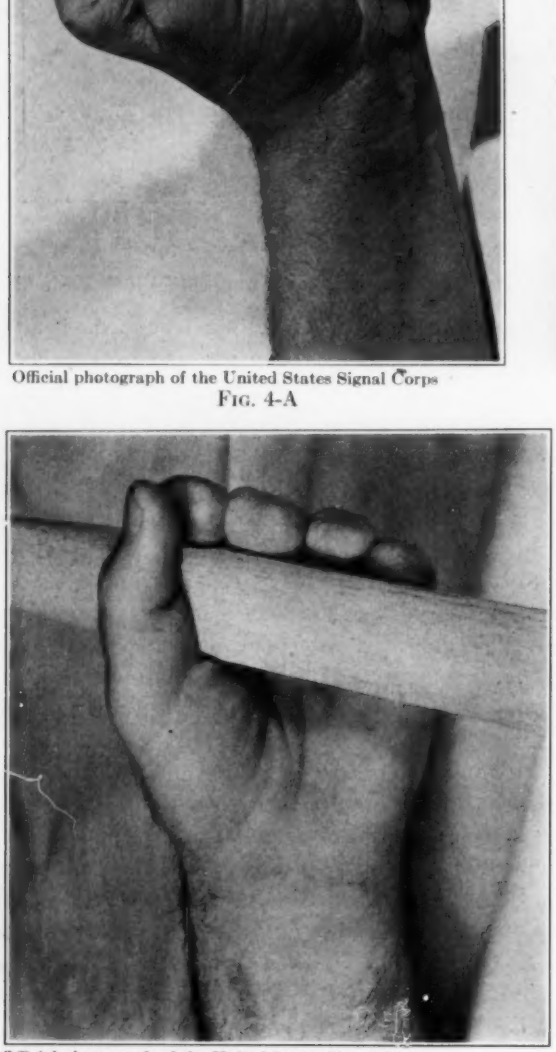

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FIG. 4-C

Multiple finger amputations

Fig. 4-A: Amputation of the index and middle fingers at the metacarpophalangeal joint, demonstrating the stabilizing effect of the breadth of the palm in grasp.

Fig. 4-B: The index and little fingers, the polar elements of the fingers, are the most important for the stability of the grasp.

Fig. 4-C: Multiple-finger amputation, demonstrating poor grasp. Hook action is practically lost, and pinch is poor in this type.

enhances the function of the palm. In performing this type of amputation, the line of incision should be so placed that it will not interfere with the function of the web. This is most conveniently done by an incision, starting over the palmar side of the finger in the web between the index and middle fingers, and passing radially about one-fourth of an inch proximal to the flexor crease, thence dorsally to the ulnar side of the metacarpal head of the index finger; a second limb of the incision starts dorsally at the ulnar side of the index finger at the point of origin of the first incision, and courses proximally along the ulnar side of the metacarpal shaft to its base. This will afford a wide exposure of the underlying metacarpal bone to facilitate its removal, and upon closure of the wound the suture line will lie well away from the web (See Figure 1).

The amputation of any other single finger does not require specific comment, except to stress the maintenance of all possible length and the preservation of the proximal portion of the proximal phalanx whenever possible. This will add considerably to the appearance of the hand by maintaining the finger webs in their normal relationship and will also add a great deal to the strength of the palm.

When the loss of the index and middle fingers together is inevitable, all possible length should be maintained. It is of prime importance to retain the metacarpal heads. This leaves a functionally better hand, and preserves the breadth of the palm, which is of great value in grasp and more than compensates for any interference with the web space (Fig. 4-A). When the index and middle fingers are missing, the strongest finger elements for grasping, hooking, and pinching are lost, for these are the strong and relatively fixed digits which contribute to the finer coordinated movements as well as to strength.

The combinations of amputations involving two or more fingers are numerous and need not be discussed in detail here. In general it may be said that no matter what the combination, as much as possible of the index and middle fingers should be preserved, for they are the most important in grasp, pinch, and hook. In grasp, where breadth is vital, the polar elements should be as far apart as possible. Thus the index and little fingers alone are more valuable than any other two fingers in combination (Fig. 4-B). In partial loss of all fingers, where only stubs remain, the hand is relatively useless (Fig. 4-C).

Metacarpal Amputations

Amputation of the second metacarpal has already been discussed under the index finger.

Occasionally amputation through the metacarpals of both the index and middle fingers together will be imperative. To ensure a satisfactory web, the metacarpals should be resected at their bases. Any length distal to this is of no value, since the bones will usually be mobile, unstable, and painful. In the formation of the web, care should be taken to break the incision line by a zig-zag method in order to ensure that secondary contracture (Fig. 6-B) will not take place. In the combined amputation of the metacarpals of the index, middle, and ring fingers, the metacarpal bones should be excised so that the web drops in a gradual arc from the metacarpal head of the little finger to that of the thumb. These bones should be resected sufficiently, so that there is no protrusion into the web itself. This maintains the maximum efficiency of the palmar surface. In an amputation through the fifth metacarpal alone, the bone should be maintained at its maximum length, for in this instance there is no web to consider, the cosmetic appearance is better, and it provides a base for the attachment of the adjacent intrinsic muscles. Unlike the radial side of the hand, the ulnar side is naturally mobile in construction and in function, and for this reason the bone may be left long without detriment, thus helping to maintain the breadth of the palm.

In an amputation through the fourth and fifth metacarpals together, the same principles apply, although the fifth metacarpal should be left slightly shorter than the fourth to improve the cosmetic appearance and to avoid a projecting bone end under the skin.

Amputations involving either the third or fourth metacarpal result in one of the most serious disabilities of the hand. The stabilizing effect of the transverse ligaments of the palmar arch is lost, and for this reason rotary disturbances of the finger may occur (Fig. 5-B). In the normal hand it will be noted that as each finger is flexed individually, it points to the tubercle of the navicular bone. In the amputations just mentioned, the adjacent fingers will be found to rotate either toward or away from the amputated metacarpal, usually the latter. The commonly accepted treatment for correction of these rotary deformities is to stabilize the palmar arch by completely resecting the involved metacarpal, then to approximate the adjacent metacarpal heads together, so that a new ligament of fibrous tissue will form. However, some rotation usually persists after operation; also, the palm is narrowed (Fig. 5-C). Although function is improved, it is not to so great an extent as might be desired. To correct this condition, the following operation is suggested as one which might meet the need of the situation, although the authors have not as yet performed the operation: With the metacarpals of the remaining fingers placed in a neutral position, a bone graft, consisting of a large flat piece of ilium, countersunk into

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FIG. 5-A

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FIG. 5-B

Amputation of the middle finger

Fig. 5-A: Normal grasp in amputation at the metacarpophalangeal joint.

Fig. 5-B: Marked rotation of the index and ring fingers in amputation proximal to the metacarpal head.

Fig. 5-C: Complete excision of the middle metacarpal. The hand is narrowed and some rotation of the index and middle fingers persists.

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FIG. 5-C

a slot on the side of the adjacent metacarpals would, when bony union occurred, eliminate rotation, and would maintain the full width of the palm. A single small strut of bone would probably not withstand the stress and strain.

In cases of metacarpal amputations, care must be taken to prevent damage to, or sacrifice of, the intrinsic muscles, which would destroy the ability to spread the finger adjacent to the amputation site.

Amputations of the Thumb

The thumb is the most vital single digit in the hand. With its total loss, the hand becomes relatively useless, since grasping and pinching are lost, with only hooking and substitution movements remaining. Every fraction of an inch is essential to function. In acute traumatic cases, therefore, every effort should be made to save all possible length. The only indication for complete or partial amputation of a thumb is loss of blood supply. Every effort for reconstruction is justifiable. Even after severe injuries, with involvement of bones, joints, tendons, nerves, and skin loss, a more satisfactory thumb can be obtained by orthopaedic and plastic procedures than by any prosthesis.

When the thumb is partially amputated, it will often be valuable to deepen the web between the thumb and pinch-finger. This may be accomplished by means of a Z-plasty. The incision starts in the palm of the hand overlying the base of the third metacarpal and

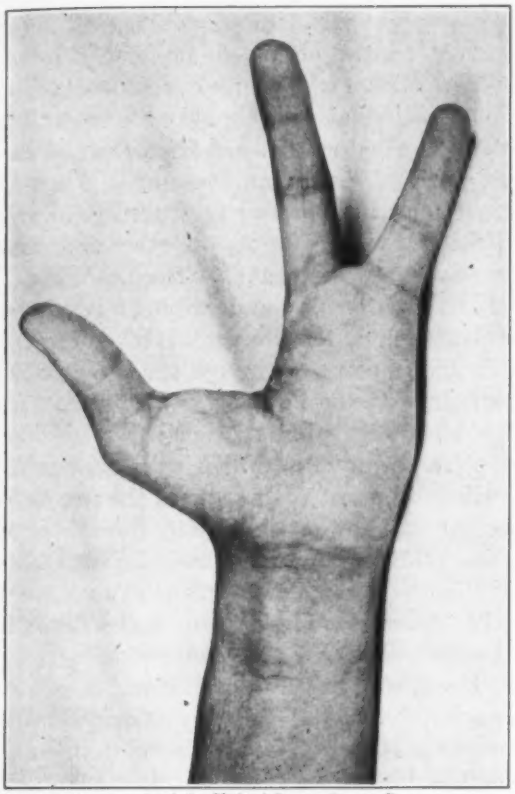

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FIG. 6-A

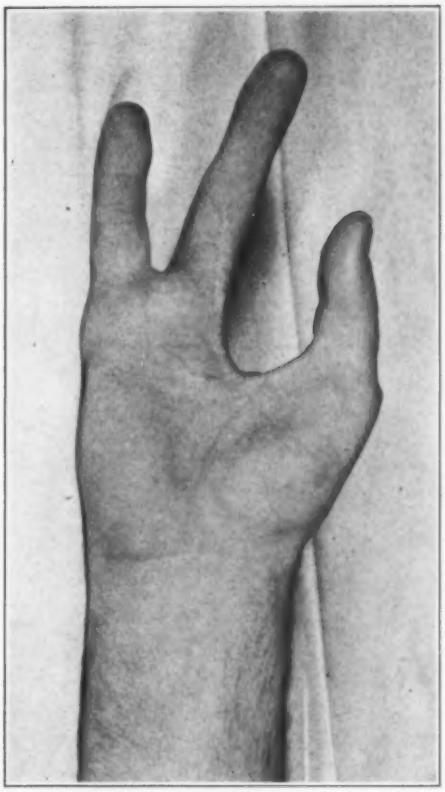

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FIG. 6-B

Fig. 6-A: Amputation of the index and middle fingers at the carpometacarpal joint, secondary to a grenade wound. Grasp was poor, because of the loss of the stabilizing effect of the radial part of the palm and the loss of the two strongest fingers. Pinch was good, hook was weak.

Fig. 6-B: A case similar to that shown in Fig. 6-A, demonstrating loss of spread between the thumb and ring finger, because of a contracture in the web.

follows the thenar crease to the radial aspect of the metacarpophalangeal joint of the index finger. From this point, the incision swings directly across the web space to the dorsal surface of the thumb. The height of the incision on the thumb will depend on the length of the flap desired. The incision then courses proximally to a point between the bases of the first and second metacarpal bones. Here again the length of the incision depends on the depth of the web desired. This results in two triangular skin flaps,—one, the palmar flap, with its base along the thenar eminence and its apex at the base of the index finger, and the other, the dorsal flap, with its base lying along the index metacarpal and its apex over the dorsum of the thumb. The shorter the thumb, the deeper the web must be. Frequently, in order to obtain the maximum depth, it will be necessary to resect a portion or all of the adductor and opponens pollicis from their attachments to the thumb and third metacarpal. After careful hemostasis is secured, the palmar flap is swung dorsally around the thumb, so that its apex lies at the proximal end of the base of the dorsal flap. The dorsal flap is then swung palmward, so that its apex lies at the proximal end of the palmar flap. The suture line between the two will now lie through the mid-portion of the web from its anterior to its posterior aspect. It will frequently be found that a skin defect remains over the dorsum of the thumb. This may be covered by a free, split-thickness skin graft. When there is partial amputation of the thumb in combination with amputation of the index finger near its base, the most satisfactory reconstruction of the web may entail the removal of the second metacarpal near its base (See Figure 1).

In total loss of the thumb, complete reconstruction of the digit will give the most

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FIG. 6-C

Amputation of the ring and little fingers secondary to injury by a high-explosive bomb fragment. Pinch is normal, hook is strong, but grasp is unstable due to narrowing of the palm. These patients substitute the hypothenar eminence for the ulnar side of the palm.

satisfactory result. First, a tube graft is constructed on the abdomen, preferably by the method of Bunnell. Three or four weeks later, when the circulation in the tube has been established, one end is detached from the abdomen and attached to the thumb stump. When sufficient time has elapsed to ensure good graft nutrition from the stump, the other abdominal attachment of the tube is freed. When all wounds have healed and excellent circulation has been assured, a bone graft is taken from the tibia and implanted through the tube, or skin graft, into the underlying bone. Great care must be taken to place the newly formed thumb in such a position that, when it becomes united, it will act against the fingers in the functional position and not lie uselessly by the side of the hand. Next, motor power must be supplied to the thumb by tendon transplant to a point several centimeters above its base, and a flexor, an extensor, and an opponens motor supplied. The muscles transplanted in each instance will depend on the available supply of non-essential tendons. It must be remembered that the abdominal skin will not contain the sensory endings which are present in normal palmar skin, and only the degree of sensation in the abdomen with its limited tactile and proprioceptive sense can be expected after regeneration.

Bunnell's ingenious transplant of the index finger to the thumb is an alternative method for restoration of the thumb. The technical difficulties encountered in this procedure restrict its use to experienced hand surgeons.

Special plastic procedures, such as transplantations of toes or portions of the foot to the hand, are generally not desirable, except in rare instances. Finger lengthening is not recommended, because of the poor function of the part afterward, due to absence of joints, and because of the poor cosmetic result, due to absence of the nail and poorly matching skin.

SUMMARY

The principles of amputation of the fingers and hand have been discussed. Emphasis has been placed upon the three fundamental units of hand function,—grasp, pinch, and hook. Careful consideration of each of these elements is the key to optimum end results.

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A STUDY OF TYPICAL PARACHUTE INJURIES OCCURRING IN TWO HUNDRED AND FIFTY THOUSAND JUMPS AT THE PARACHUTE SCHOOL

BY MAJOR C. DONALD LORD, *Medical Corps*

Surgeon, The Parachute School

AND LIEUTENANT COLONEL JAMES W. COUTTS

Assistant Commandant, The Parachute School

Parachute jumps at The Parachute School have increased progressively from their inception in 1941 to the time of this writing. Parachute injuries at The Parachute School have proportionately decreased progressively, until at the present time a "jumper" has roughly only a one per cent. chance of being injured in any way in any one parachute descent. This remarkable increase in parachute activities, in spite of the decrease in the rate of injury, establishes a wealth of clinical material for study. This clinical material has been used in preparing this report.

Certain types of training injuries and fractures from jumping have occurred repeatedly, until there now exist several clinical entities recognized as typical parachute injuries. These will be discussed subsequently.

In this report, the writers have analyzed the material at hand according to:

1. The type of injury most common to each of the four training stages, and the anatomy, physiology, and, where possible, the mechanics involved in producing the injury.
2. The immediate and follow-up care of the injured provided at The Parachute School.
3. New training techniques and apparatus accounting for the diminishing rate of injury.
4. New methods of selection employed in choosing parachute personnel.

An "injury" has been arbitrarily defined as a condition directly resulting from training, which causes the student to lose one day or more from duty. Minor sprains, lacerations, contusions, or exhaustive states in students who can be rehabilitated at The Parachute Medical Unit and returned to duty within a few hours are not considered statistically as "injuries".

The parachute course of training consists of four stages briefly described for the purpose of orientation as follows:

1. *A Stage:* calisthenics, rope-climbing, running, and jumping from low four-foot to six-foot platforms into sawdust pits.
2. *B Stage:* tumbling, trainasium, landing trainer, jumps from mock doors (four to six feet), jumps from mock towers (thirty to thirty-five feet), and suspended-harness drill.
3. *C Stage:* daily jumping from the 250-foot towers (free and controlled), and landing by parachute on sawdust. Tumbling is reviewed, and parachute control is practised.
4. *D Stage:* The applicant makes the necessary number of plane jumps to qualify as a parachutist; the jumps are made from a plane in flight, and the landing is made on level and uneven terrain.

The physical hardening accomplished through A-Stage training puts most applicants at something near physical perfection. It has been found that in men physically at their best, fear phenomena in the apparatus of the next three stages are less prone to develop.

The strain or tear of the right rectus muscle has proved to be the most frequent cause of disability in A-Stage training, and the most interesting clinically, since it closely simulates acute appendicitis. This occurs in rope-climbing, presumably when the lower extremities are raised at right angles to the body, and the legs grasp the rope, as shown in Figure 1.

It is believed that in the attempt to reach the top of the rope, an unusually strong

effort is made, in some cases causing a definite sharp pain in the abdomen and resulting in the following clinical syndrome: The patient appears at The Parachute Medical Unit, complaining of pain in the abdomen, and walking with the hips slightly flexed. The simple process of getting on the examining table is difficult because of the pain. With the patient standing, the abdomen appears relaxed, there being no effort to "hold in the abdomen". In those cases with hematoma formation, a definite bulge can be seen along the course of the rectus muscle. Inspection further reveals some subcutaneous ecchymosis (after four to seven days have elapsed), extending downward from the point of maximum tenderness. The muscle is exquisitely tender on light palpation, and the patient resists any sort of deep pressure. When asked to raise the body from the prone position, keeping the lower extremities flat on the table, severe pain is experienced. These cases occur in the right rectus in 90 per cent., and in the left in 10 per cent. It is believed that this is due to the greater effort which is exerted on the right side in the majority of cases. A white blood count of 9,000 to 11,000 occurs the day following the injury, with polymorphonuclear leukocytes ranging from 70 to 80 per cent. Now that the cause has been determined, the diagnosis can readily be made, but many patients have been hospitalized for observation for appendicitis. One patient was operated upon. A hematoma below the rectus was found. The wound was closed and the appendix was not removed.

Since the act of tumbling has proved effective in disseminating the shock of landing, the proper technique of tumbling is drilled into the applicants over and over again daily, until a smooth, properly executed tumble automatically follows contact with the ground from any height. This emphasis on tumbling leads to the typical injury of Stage B,—the acromioclavicular contusion and the acromioclavicular separation. Figures 2 and 3

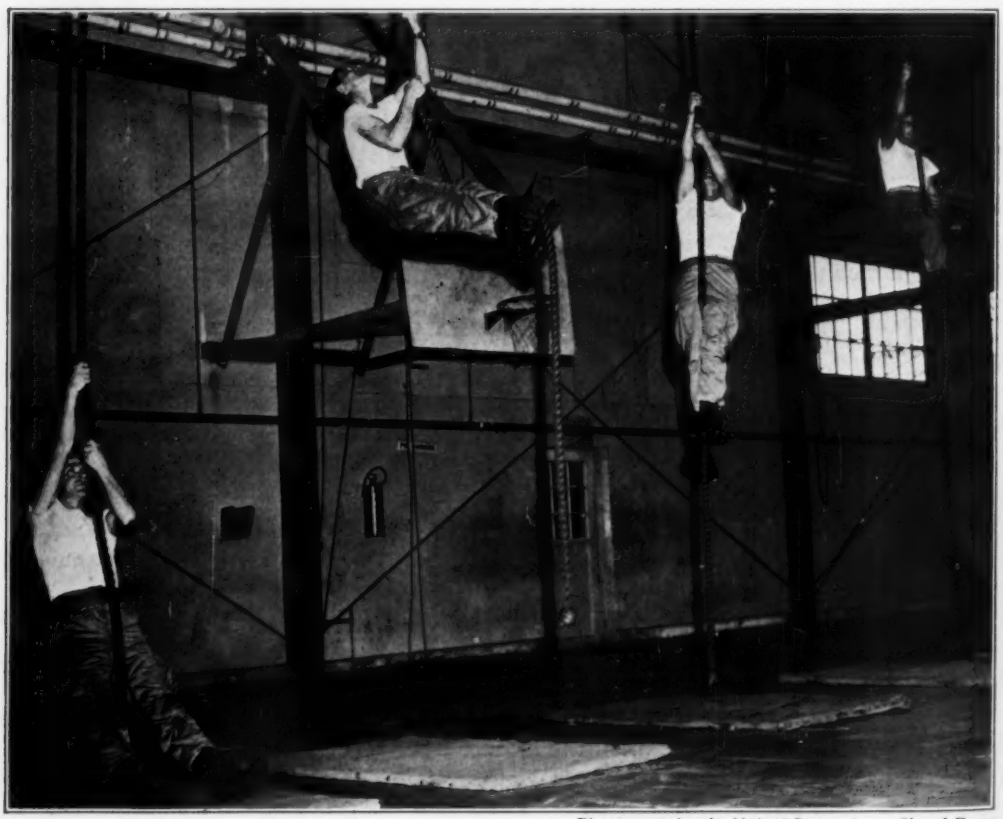

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FIG. 1

Illustrating the mechanism of the "right rectus strain or tear".

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FIG. 2

Tumbling from the "landing trainer". If the tumbling is improperly executed, the point of the shoulder strikes the ground with greatest force, resulting in acromioclavicular injury.

show two training situations, involving tumbles which are being properly executed.

The shoulder tip should not touch the ground; the forearm, held rigidly by the triceps, acts as a bar over which the body rolls. When the triceps is relaxed, the shoulder comes in direct contact with the ground, and the acromioclavicular injury occurs. Separation of the acromioclavicular joint in these injuries involves only the tearing of the articular capsule in some cases; the coracoclavicular ligaments remain intact and prevent the scapula and acromion from being displaced downward.

In the more severe cases, the capsule and the coracoclavicular ligaments are torn,

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FIG. 3

Illustrating in greater detail the mechanism of acromioclavicular injury.

and the acromion, being completely separated from the clavicle, is displaced downward by the weight of the upper extremity. In Figure 4, the acromioclavicular separation is marked, but the scapula and the acromion are depressed only slightly.

In one case it was felt that the coracoclavicular ligaments had been stretched, but that the connection to the clavicle had been maintained. This case was treated by placing a block in the axilla and strapping it to the body; an additional strap extended up over the lateral end of the clavicle and the shoulder, and down posteriorly, and was attached to the block behind the axilla. The elbow was raised by means of a sling. This patient returned to full jump duty after five months, has now qualified as a parachutist, and has no symptoms referable to the shoulder.

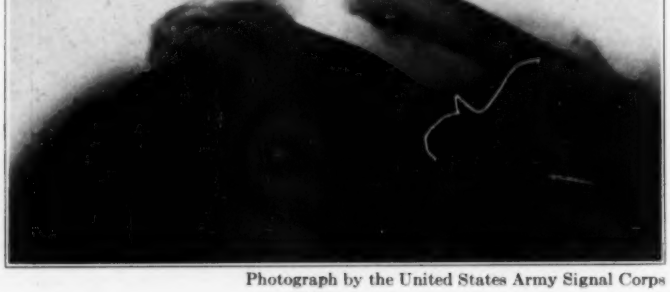

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FIG. 4

Roentgenogram illustrating typical acromioclavicular separation.

The less severe injury—namely, the simple acromioclavicular separation with slight, if any, tearing of the capsule—responds to immobilization of the upper arm and shoulder for from two to four weeks. These students are ready for full parachute duty in this length of time, with no other treatment than physiotherapy and rest.

In C and D Stages, the injuries have a common cause,—namely, landing by parachute. The injuries, while more frequent in D Stage, involve the same mechanism, and both will be described together. There are two typical parachute leg injuries. The first, resulting from a parachute jump, is the double fracture, involving the lower third of the fibula and the posterior lip of the tibia. The mechanism of this fracture is explained on the basis of a double force. It is thought that when this fracture occurs, the foot is rotated externally and is forced posteriorly on contact with the ground. When the foot is rotated externally, the anterior portion of the body of the talus (astragalus) presses against the anterior border of the inner surface of the external malleolus, forcing it outward and backward. If the force is sufficient, and if the inferior tibiofibular ligament remains intact, this force tends to cause an oblique fracture of the lower end of the fibula, usually about two inches above the tip. The posterior force is the result of the forward motion of the foot as it strikes the ground. The impact is transmitted up the metatarsals, through the tarsus, and forces off the posterior tibial lip. In the presence of a ground wind, and with oscillation at the time of landing, a more violent eversion of the ankle may occur, resulting in the trimalleolar fracture described by Lewin in his study of the foot and ankle. In these cases, fracture of the internal and external malleoli and the posterior tibial lip occurs. This trimalleolar fracture, however, is considerably less frequent than that involving the fibula and posterior tibial lip alone.

Figure 5 shows the position of the feet and legs and the landing attitude as the parachutist approaches the ground. Figure 6 shows a fracture of the ankle involving not only the usual lower end of the fibula and posterior tibial lip, but also the internal malleolus, which occurs in the more violent eversions of the ankle on landing.

These fractures were common prior to some recent changes in landing attitudes. The "original parachute fracture" just described has recently begun to be replaced by a fracture of the upper third of the fibula or dislocation of the fibular head. This is due to the fact that greater support is given to the ankle by having both feet held firmly together at the moment of striking the ground. However, coincident with the decrease in the

fracture just described, there has been an increase in fractures of the upper third of the fibula and also in dislocation of the fibular head. Since the latter situation is simpler to handle surgically, and since the convalescent time is substantially less, this is considered a favorable change.

This second "typical parachute injury" we have called the "silent fracture", since so frequently the upper third of the fibula will be fractured and the patient will exhibit few, if any, symptoms. It is not unusual for the fracture to occur in C Stage and the soldier proceed with the actual plane jumps of D Stage before reporting for medical care. Figure 7 shows a fractured fibula which occurred on Friday of one week, although the student did not appear at the Medical Unit until Tuesday of the next week, when he complained of "a little" pain. It is our belief that a fracture of the upper third of the fibula could very frequently be misdiagnosed as a sprained muscle, if the possibility of this "silent fracture" were not kept in mind.

Photograph by the United States Army Signal Corps

FIG. 5

Parachutists in descent. Preparation for ground contact has been properly made.

Such relatively *painless pathology* can undoubtedly occur only because the fibula does not enter into weight-bearing. In a series of thirty-five cases diagnosed recently, only ten students reported for treatment at the time of the fracture. The other twenty-five reported for "slight pain" in the upper outer aspect of the leg seven to thirty days after the injury. Many showed marked callus formation in the original roentgenogram. It is felt that some cases of fracture in the upper third of the fibula are never diagnosed as fractures. These fractures have become more frequent in our series as fractures of the lower fibula have decreased, as a result of the ankle support afforded by landing with the feet and ankles held firmly together.

Dislocations of the fibular head have occurred in a small series of cases, but are becoming more frequent as the ankle injuries diminish in frequency. Figure 8 shows the fibular head in a dislocated position.

It is felt that the sideward landings, which occur in oscillations, result in a tendency to "spring" the fibular head from its position, or fracture it in the upper third.

Key and Conwell mention the possibility of backward, forward, outward, or upward dislocation of the fibular head. The dislocations of the fibular head occurring in parachute landings are primarily lateral dislocations, resulting from the "springing" action described. The attachment of the tendon of the biceps femoris would tend to dislocate it posteriorly and upward, but this type of dislocation has not occurred in our series. The diagnosis is not difficult, since the bone is subcutaneous and can be readily palpated. These dislocations are sometimes reduced on the jump field by the ambulance surgeon or

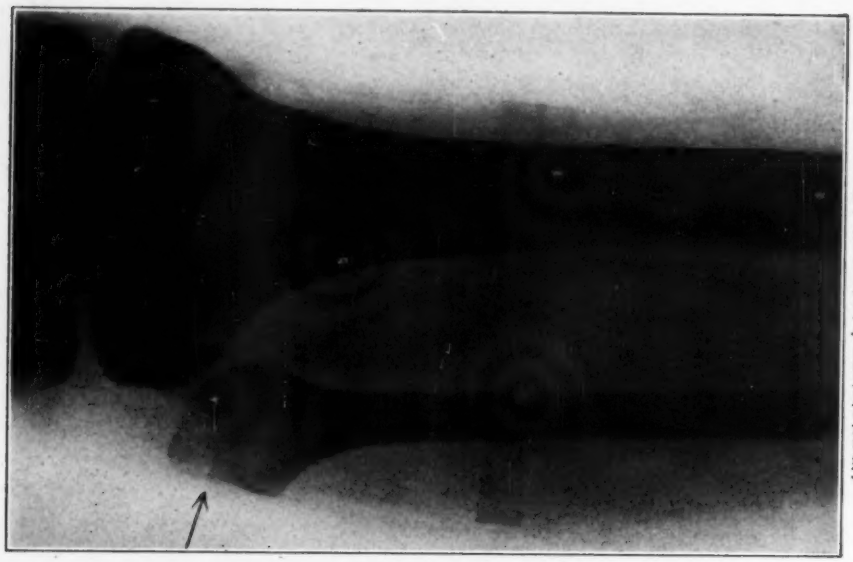

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FIG. 8

Typical dislocation of the fibular head. Here, as in the "silent fracture", there is a minimum of symptomatology. These are infrequent.

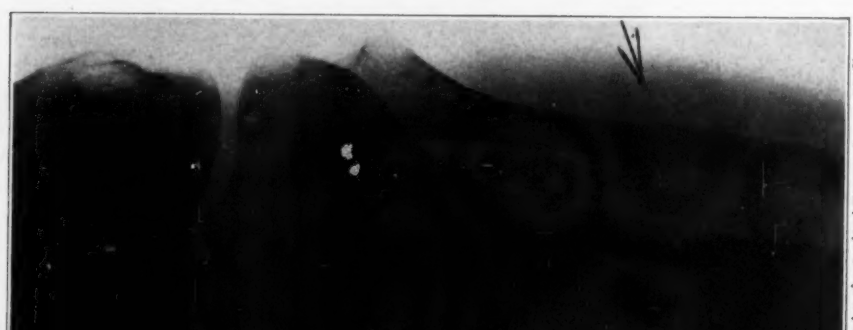

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FIG. 7

Illustrating the so-called "silent parachute fracture" of the upper fibula. The term "silent fracture" has been coined to indicate the relatively painless nature of this fracture.

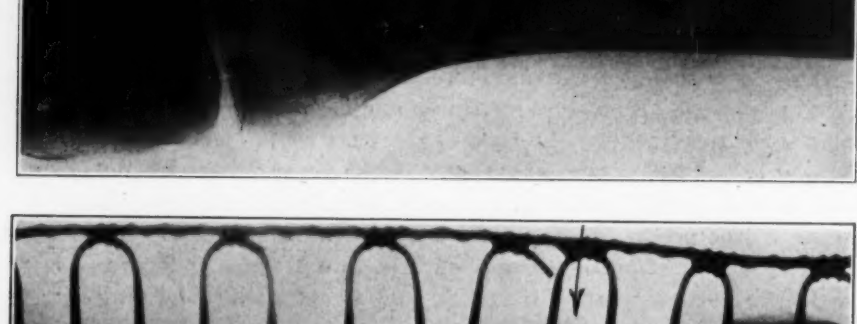

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FIG. 6

Typical parachute fracture of the ankle, involving both tibia and fibula.

at The Parachute Medical Unit after roentgenographic examination. The procedure is strong inversion of the foot and direct pressure over the fibular head. An elastic bandage is applied, and the patient is given crutches and is kept ambulatory. We have seen no evidence of peroneal-nerve involvement yet. One medical officer in parachute training, having a dislocated fibular head, reported a numbness of the foot, lasting several days after the accident. There was no tendency to muscle weakness, or "foot-drop". We are of the opinion that the relation of the peroneal nerve to the fibular head is such that with slight or moderate dislocation of the fibular head no pressure is exerted on the nerve. Furthermore, reduction is accomplished very early in these cases, and, if pressure on the nerve does occur, it is relieved promptly.

These two clinical syndromes, one involving the ankle, the other involving the upper fibula, have occurred so frequently that they are now considered classical parachute entities.

With the opening shock of the parachute, while the soldier is falling freely, any type of fracture or injury may occur, if the body position is incorrect. The most unusual, recently, has been a deep laceration of the perineum, extending from the scrotum to and involving the sphincter ani, and extending deeply enough to expose the lower segment of the rectum.

This was caused by the parachutist doing a forward somersault in the air with his legs apart before the parachute opened. The suspension lines went between his legs. When the parachute opened in the propeller blast, the great force of the taut suspension lines was exerted on the perineum causing the deep laceration. When the body position is normal, this great opening force is directed to the body harness from the suspension lines. It is thought that this accident occurred because the parachutist "dived" rather than "jumped" from the plane in flight; and because he neglected to keep his feet and legs together at the exit. Such cases are rare, but are of great clinical interest because they show the hazards involved when the "rules" are not followed.

THE IMMEDIATE AND FOLLOW-UP PROVISIONS FOR CARE OF THE INJURED

The fractures discussed in this article are seen long before swelling has had time to occur, because of the preparedness which exists in The Parachute School for immediate handling of injuries. Very frequently fractures can be palpated by the examining physician, before the obscuring action of oedema has intervened.

Students with injuries occurring in A Stage, B Stage, and C Stage are picked up by the ambulance from The Parachute Medical Unit within a very few minutes from the time of the injury. Jumping injuries occurring in D Stage are handled as follows:

On the jumping field there is an aid man assigned to watch the descent of every parachutist. He is within six feet of the parachutist when the latter lands. If there is any evidence whatever of injury, the aid man unfolds his red flag. Two ambulances and doctors are assigned daily to the field. One responds immediately to a waving red flag. The diagnosis is made within a matter of two minutes, as a rule, from the time of injury. The injured member is splinted, and the patient is transported to The Parachute Medical Unit where roentgenograms are taken. Wherever possible, if no fracture exists, ambulatory treatment is encouraged. Patients with fractures are admitted to the Hospital; those with sprains, regardless of their severity, contusions, and the like, are supplied with crutches, and are kept ambulatory.

On two occasions The Parachute Medical Unit has conducted a series of studies to determine the advisability of novocain injection of sprains. The immediate relief of discomfort by this method cannot be disputed. However, with early icing, tight binders, and the use of crutches for twenty-four hours, the pain is not a troublesome problem. It is believed that novocain injection has definite value in selected cases, where the pain is severe, or for those patients who must walk immediately. The great majority of pa-

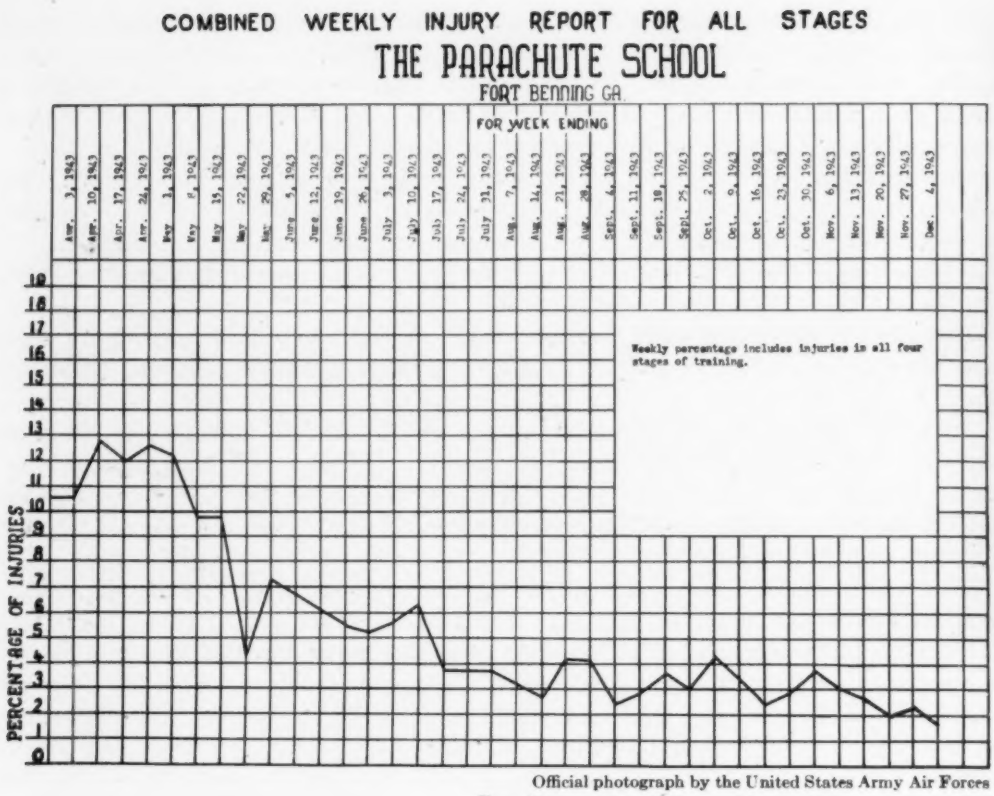

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FIG. 9

Graphic representation of how all injuries, both in the jumping stage and the prejump training stages, have been markedly decreased.

tients, however, receive no injections of novocain under our present method of treatment. The length of disability is not shortened by novocain injection, possibly because almost complete healing is required before a soldier is permitted to return to jumping status.

In the first twenty-four hours, tight bands, icing, and immobilization is the treatment of choice. After the first twenty-four hours, warm applications, gentle massage, and early active motion is the course followed. The Physiotherapy Department in The Parachute Medical Unit handles hundreds of men daily, using infra-red or ultra-violet lamps, whirlpool baths, alternating hot and cold baths, and massage.

NEW TRAINING TECHNIQUES AND APPARATUS ACCOUNTING FOR THE DIMINISHING RATE OF INJURY

It is believed that certain revisions of the landing method taught at The Parachute School are in some measure responsible for a distinctly diminishing rate of injury. This decrease was accomplished in spite of an increase in the training load of The Parachute School since July 1943. A revision of technique entailed:

1. Landing with the feet together, legs bent slightly at the knees, and the weight of the body slightly forward over the feet. Legs are held so that the knees are together. The muscles are not tensed, yet not relaxed. The leg muscles are alert to take up the landing shock.

2. A variation of the previously taught tumbling technique, so that proper landing can be made during ground approaches that are angular to the line of drift during a parachute descent. It was discovered that, although the desired approach was a forward drift when landing (See Figure 5), in a large percentage of instances, backward or oblique landings occurred.

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FIG. 10

Parachutists in various stages of the plane exit. It is at this moment that occasional "freak" accidents occur.

Further diminution of the rate of injury was accomplished by exacting supervision of each student during this period of training before entering D Stage. Careful attention to the maintenance of all equipment and training aids was found also to have some value.

A study of the parachutists in Figures 3 and 5 shows the value of the training in Stages A, B, and C. Figure 5 indicates lessons in landing technique that were properly learned. In the early days of parachute training, when the student load on the School was small, the Assistant Commandant was able to select the most favorable weather, when allowing his novices to jump for qualification. However, when it became necessary for The Parachute School to increase its output, it became increasingly difficult to pick ideal jumping weather for the novice. The directive to "qualify the men" made it impossible to limit their jumping to ideal weather conditions, as in the past. The decreased injury percentage appears all the more remarkable in view of these conditions.

Strong ground winds frequently set up a pendulum-like motion of the parachutist, in which the apex of the parachute is the fixed and the parachutist himself the moving end of the pendulum. This swinging motion, or oscillation as it is termed, can materially reduce the parachutist's opportunity for making a landing, uninjured. When the old method of landing was taught, the novice's feet were approximately the width of the hips apart. It is apparent that a sideward oscillation would bring the landing shock of all the body's weight upon one or the other foot. This increased the possibility of sprain or fracture. The new method of landing—that is, with the feet together—distributes the shock of an oscillating landing with almost perfect equality to both feet and legs. Careful records maintained at The Medical Unit of The Parachute School, covering thousands of injuries, have permitted the preparation of Figure 9.

The new method of landing was inaugurated in the A Stage on June 12, 1943. It will be noted that since that time there has been a marked decline in the weekly percentages of combined injuries. This average was not subjected to the violent fluctuations which

had previously characterized it. Comparison of the 1943 seasonal averages with those of 1942 reveals that in each case the percentage of combined injuries is lower.

SELECTION METHODS EMPLOYED IN CHOOSING PARACHUTE PERSONNEL

The selection of parachute personnel is done with utmost care. All incoming applicants to the School have first been examined by their Unit Medical Officer, who is supplied with a copy of the physical requirements for parachute admission. This serves as a gross screening process in weeding out obviously poor material. On admission to the Receiving Battalion at The Parachute School, all men are subjected to an examination system at The Parachute Medical Unit, which rules out anatomically and psychologically poor material. The men are passed through a series of rooms and individually examined from a psychiatric viewpoint, with stress being laid on various phobias for the detection of any lack of desire for training of this severity. They then proceed through the various stages of the physical examination, with particular stress being placed on anything which is symptomatic at present,—such as old lumbosacral sprains, old fractures still painful, old retracting scars, and any history of symptoms referable to the head (dizziness, blackouts, fainting spells, *et cetera*). Men with potential hernias are ruled out, for fear of exaggeration of the hernia during training. All applicants with heart murmurs are ruled out, unless the murmurs can be definitely proved to be functional. All those with questionable visual acuity without glasses are ruled out, unless their vision is 20/40 or better bilaterally. Venereal disease disqualifies a man on the original examination. If venereal disease is contracted during the course of training, the soldier is immediately removed from parachute training and is disqualified. Luetics who have had what is considered adequate treatment, and whose blood and spinal-fluid serology are negative, are acceptable. These applicants are not considered as having venereal disease. The elimination of these conditions results in rejections of between 10 and 15 per cent. of all applicants reaching The Parachute School at Fort Benning, for training.

Further selection is accomplished through the observations of the Stage Leaders in noting hesitancy or actual inability to perform some of the preliminary low-jumping procedures.

Such selection standards result in the acceptance of the best men available. We are convinced that men physically perfect are less prone to injury in training than those with any physical impairment, and, therefore, credit some of the diminishing rate of injury to the increasing severity of standards of selection.

The four types of physical injuries which have been discussed are parachute entities, proved by their repeated occurrence in soldiers taking this course. Their frequency, it is felt, has been markedly reduced in the past six months, and those occurring now are recognized as unavoidable (at present) in the production of qualified parachutists.

CONCLUSIONS

1. This survey covers in excess of 250,000 parachute descents at The Parachute School.

2. Statistically, any parachutist has only a one per cent. chance of injury in any one parachute descent, and this figure is decreasing.

3. Some typical medical parachute entities have now been established.

   a. Strain of the right rectus muscle.

   b. Contusions and separations of the acromioclavicular joint.

   c. Fracture of the lower third of the fibula, associated with fracture of the posterior tibial lip.

   d. The "silent fracture" of the upper third of the fibula, and less frequently a dislocation of the fibular head. The fibula may be fractured in its upper third and be relatively asymptomatic; hence, the designation "silent fracture".

4. Holding the feet together on contact with the ground, replacing the old method of holding the feet eighteen inches apart on landing, has markedly reduced ankle fractures.

The authors wish to acknowledge the active cooperation of the X-Ray and Orthopaedic Services at Station Hospital, Fort Benning, Georgia. The photographs were reproduced through the courtesy of the Post Signal Photographic Laboratory, Fort Benning, Georgia, and Base Photographic Section, Lawson Field, Georgia. The figures quoted were obtained from the official records of The Parachute School.

Both authors are qualified parachutists.

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FATIGUE FRACTURES

BY MAJOR PERCIVAL A. ROBIN AND MAJOR SAMUEL B. THOMPSON

Medical Corps, Army of the United States

From the Station Hospital, Camp Howze, Texas

In a period of sixteen months, fifteen cases of insufficiency fractures occurring in bones other than the metatarsals have been treated in this Hospital. They have been classified in this category, because of the absence of a history of trauma sufficient to produce a true fracture. Of the fifteen cases considered, thirteen were in the tibia, one in the femur, and one in the pubic bone. Of the tibial fractures, two were bilateral and one of these was multiple.

CLINICAL FEATURES

The usual history elicited on admission was that a generalized aching pain had developed in the involved extremity. The pain had come on during or shortly after an extended march and had continued to grow steadily worse with increased activity. Finally, the pain had become localized at the site of the fracture. The patient frequently noted swelling of the extremity, occurring early in the course of this condition.

On physical examination, localized tenderness was found at or near the fracture site, associated with swelling in this region and generalized oedema of the involved extremity. If the patients were admitted in a later stage, a palpable mass, produced by exuberant callus, was found. It was discovered, through clinical experience with fatigue fractures, that these clinical manifestations were sufficient to make one suspect the presence of this entity. Any one of the findings occurring singly also warranted roentgenographic investigation.

ROENTGENOGRAPHIC FEATURES

If the roentgenographic examination was made in the initial phase of the fracture, the earliest manifestation noted was an infraction involving the cortex. The tibia was the bone most commonly involved, and the fracture, as a rule, could be seen either medially or

posteriorly six to twelve centimeters from the proximal articular surface. One to two weeks later, however, a localized area of subperiosteal new-bone formation, sometimes rather extensive, was observed about the fracture site (Fig. 1). Under treatment, the fracture line disappeared at the end of about one month. The subperiosteal new bone became dense, and this area decreased in size until finally there was only slight localized cortical thickening in the area of the old fracture. When the fractures were multiple, one fracture would be found in the usual location and the other distal to it. No matter where the fracture was, even in the pubic bone, the pattern was about the same.

TREATMENT

The routine treatment of these fractures was quite simple. The patient was brought into the Hospital primarily for rest, and later, when he was ambulant, crutches were employed until complete union had occurred.

It was found that, in the cases treated in this Hospital, the average duration of symptoms prior to admission was thirty-one and four-tenths days. The average hospital stay was forty-one and three-tenths days. Patients were discharged after complete disappearance of symptoms and upon roentgenographic evidence of firm bony union.

SEQUELAE

The high incidence of revisits to the Orthopaedic Clinic following discharge from the Hospital was quite discouraging; six of the original fifteen patients returned to the Hospital with the same complaints found at the onset. On these subsequent visits, however, there was no evidence of localized swelling, but questionable tenderness could be found. Roentgenographic findings were the same at all the revisits,—firm bony union of the fractures with no other evident lesions. One of the patients was eventually separated from the Service with a diagnosis of psychoneurosis, and two were discharged from the Army because of static deformities of the feet. A satisfactory explanation for the recurrence of symptoms cannot be offered. The percentage of recurrent complaints was higher in this group of cases than was observed in a series of similar fractures (march) of the metatarsals. Of ninety march fractures observed concurrently, only fifteen patients revisited the Clinic with complaints similar to the original, and, on careful study, ten of these were found to have other conditions of the foot which could well account for the persisting symptoms.

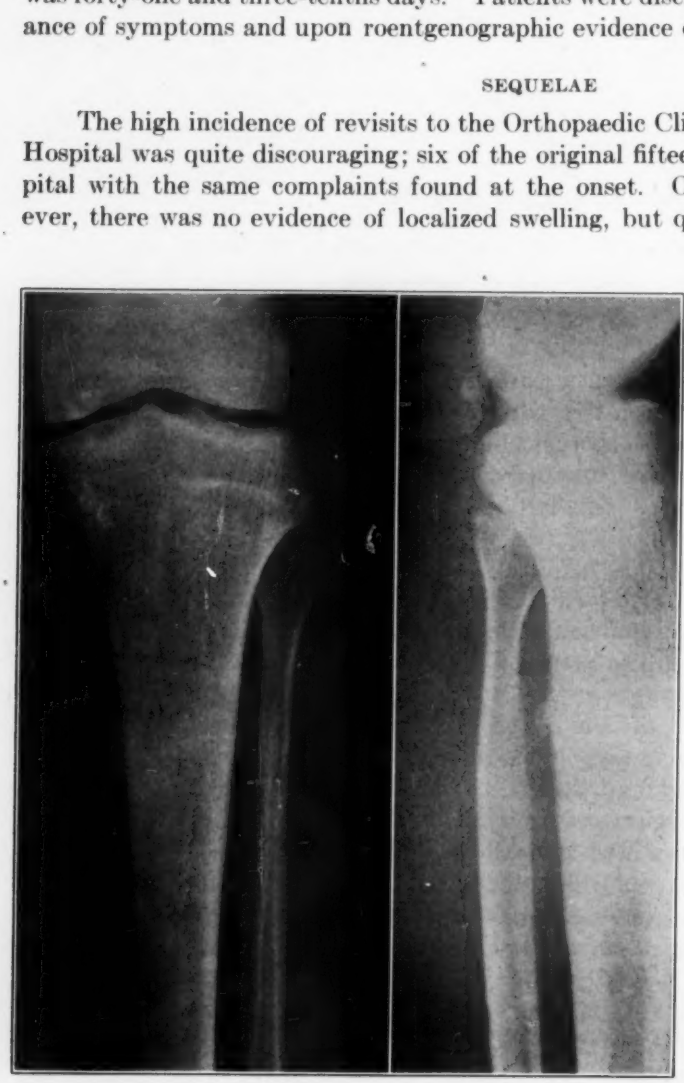

FIG. 1

A typical example of a fatigue fracture in the healing phase.

ETIOLOGY

Statistical findings gave no clue as to the etiology. The average age of the patients was twenty and nine-tenths years; the average length of service when the fatigue fracture occurred was five months; the average weight was 146 pounds; and the fifteen soldiers included in this study were occupied in nine different pursuits prior to entering the Service. The only common denominator of all insufficiency fractures studied in this institution was a history of prolonged marches. Why such fractures developed in these soldiers rather than in others has not been explained satisfactorily by our studies.

FATIGUE FRACTURE OF THE FEMUR

Two out of the fifteen fatigue fractures occurred in other bones than the tibia. One was a bilateral fracture of the pubic bone, and the other involved the lower third of the femur. The latter case warrants special consideration.

The patient reported to the Hospital on March 29, 1943, with a history of having twisted his right knee while practising routine falls, one week previous to admission. All complaints were relative to the right knee, and, on examination, slight effusion was noted in the joint. There was also tenderness over the region of the fibular collateral ligament. Roentgenographic examination of the knee showed no bony or articular abnormality, and, therefore, a diagnosis of sprained knee was made. On April 14, during the course of re-examination of this extremity, a small bony mass was palpated, arising from the right femur at the junction of the lower and middle thirds. A roentgenographic examination made on the same date disclosed a comminuted fracture at this site, with the fragments remaining in anatomical alignment. There was slight callus formation about the fracture. On close questioning, the patient could not recall any injury to this portion of the extremity. Furthermore, the trauma incident to the knee injury was very trivial in character, and could not reasonably be held responsible for the fracture. There had been no complaints relative to the fracture site, either prior to or following the initial injury. By May 22, 1943, roentgenograms showed complete union with obliteration of the fracture line. On follow-up examinations, there were no subsequent complaints. It is admitted that the advisability of including this fracture with the others in this category is open to debate.

CONCLUSIONS

The incidence of fatigue fractures, particularly in the tibia, among infantry troops in training is higher than one might expect. Many such cases may be overlooked because of the minor nature of the complaints and the failure to obtain roentgenograms on slight clinical evidence. If the entity is kept constantly in mind, many more cases will undoubtedly be uncovered.

BONE-DRILLING IN DELAYED UNION OF FRACTURES

BY MAJOR M. E. PUSITZ AND CAPTAIN E. V. DAVIS

Medical Corps, Army of the United States

From the Orthopaedic Section, Hammond General Hospital, Modesto, California

This paper is presented, not to offer a new method of bone-drilling in delayed non-union, but to emphasize a very worth-while procedure that is often neglected in the treatment of fractures. The senior author found it successful in a larger number of cases in his private practice, but this report is limited to twenty-five consecutive cases treated at this Military Hospital.

According to Campbell, a pioneer surgeon named Brenard employed multiple drill holes through the fracture site to promote osteogenesis. The first accurate description was given by Wildey in 1915, but there was no acceptance of the method. In 1919 it was again described, this time by Andrews. There was little further mention of it until 1929, when the article by Beck was published. From this time on, the method has been described in many texts, but no accurate survey has been presented. In some it is barely mentioned; in others, Böhler's book for example, it is given too prominent a rôle in the treatment of *ununited* fractures.

As a matter of fact, bone-drilling is not a method of choice in the treatment of definite non-union. Rather, it is intended for the treatment of delayed union. It is, of course, difficult to differentiate between delayed and non-union. It involves not only a question of time, but also a question of the roentgenographic findings. A delayed union may be still present at the end of ten months, whereas non-union may be present at the end of ten weeks.

There are three essential types of non-union,—namely, (1) typical pseudarthrosis with sclerosis of the ends of the fragments, (2) fibrous union with osteoporosis of the fragments, and (3) fibrous union with atrophy of disuse.

In delayed union, although there may be no discernible callus, there is no sclerosis of the ends of the fragments. In a general way it may be stated that, if there is absolutely no evidence of callus formation at the end of four to six months, delayed union may be considered to be present.

Watson-Jones has rightly stated that a large number, probably the majority, of delayed unions will ultimately unite, if immobilization is adequate and continued for a long enough period of time, following the functional method of immobilization of Böhler. However, this may take eight months or eighteen months, and certainly a proportion of these delayed unions will resolve themselves into non-unions. If a method is available which is simple, carries with it very little potential danger, and yet gives a large percentage of success, both with reference to shortening markedly the period required for full union and to reasonably averting non-union, it should be known and practised by those who treat fractures.

INDICATIONS

Delayed union is the primary indication for the use of bone-drilling. In such cases it should be performed, not eight to twelve or more months after fracture, but rather within a four to six months' period, especially if x-ray findings are suggestive of ultimate non-union.

In a number of instances, probably the majority, union would occur without operation, but it would entail a prolonged period of inactivity, which, when measured in working hours, is very expensive. This is true in industrial surgery, and particularly true in

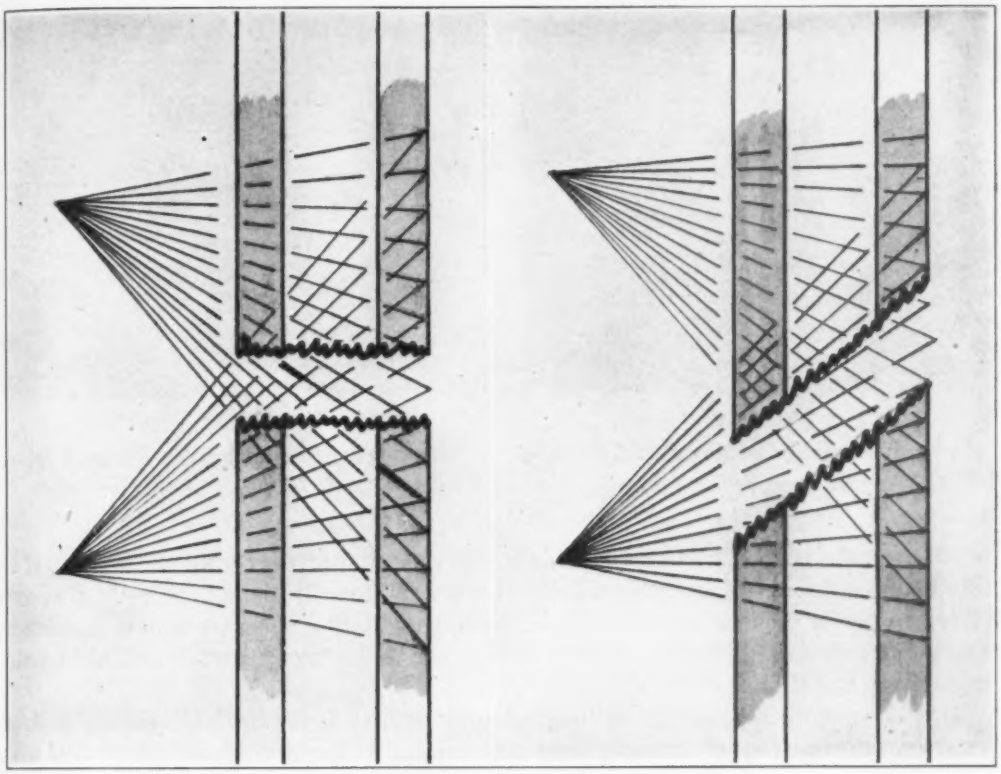

FIG. 1

Showing the technique of lining up the drill holes in the bone-drilling operation.

the Army. It is also true that bone-drilling will avert non-union in a large number of cases, and subsequent major bone operations with the many months required for a final result to be obtained.

While it is true that in many instances bone-drilling has proved to be efficacious in the treatment of non-union, it is not the method of choice. For this condition, bone-grafting is preferable.

TECHNIQUE

Open Operation

Until experience in the drilling method is adequate, open operation should be practised. The incision should be as short as is consistent with complete exposure of the fracture site. The dissection should be minimal, in order not to interfere with the local circulation. The stripping of the periosteum from the bone should also be minimal, for similar reasons. A series of thirty to fifty holes are then drilled in the following manner: Starting above the fracture site, a dozen or more drill holes are made across the line of fracture, so that they converge at the point of entrance of the drill, but diverge as they cross the fracture site. In a similar way, drill holes are made with the point of convergence below the fracture site. (See Figure 1.)

This is a bone operation, and an elective procedure. The proper preoperative preparation of the area is essential. The drill should not be very wide. Beck's wires are only one and five-tenths to two millimeters in diameter, and about ten to twenty centimeters long. It is important to use a good drill clamp,—a Jacob's chuck, for example. If the drill stock does not grasp the drill or wire tightly enough, the drill will remain in the bone and merely turn around in the chuck.

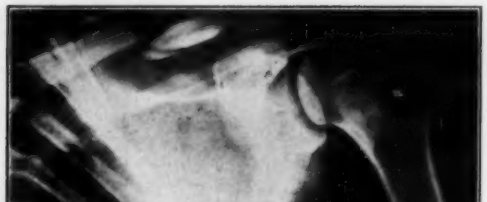

FIG. 2-A

Delayed union, five months after fracture of clavicle.

FIG. 2-B

Three weeks after drilling, showing good callus formation.

Many criticize the use of motor drills on the ground that they burn the bone. If the motor drill is allowed to rotate too rapidly, it will undoubtedly cause burning. However, all modern motor drill units are equipped with a regulating rheostat which enables the surgeon to rotate the drill at a safe rate. As long as the shavings are white and not burned, the optimum speed has not been exceeded.

If a hand drill is used, the drilling of forty or fifty holes becomes rather a chore. Moreover, the same ease of direction cannot be applied to the drill, and there is thus lost a nicety of the technique. In addition, with a hand drill there is greater tendency for the drill to follow the line of least resistance, and go repeatedly through the same drill hole. There is also the greater possibility that the drill may break.

There are certain situations in which a hand drill would probably be preferable to a motor drill. For example, in operating for delayed union of a fracture of the carpal scaphoid, the use of a hand drill would enable the operator to feel the passing of the drill from one fragment to the other, and consequently more easily avoid damage to the articular cartilage.

Campbell states that five holes should be made in each fragment and across the line of fracture. It has been our experience that this is not enough. It is preferable to use thirty to fifty drill holes. The object of the drilling of the fragments is to open up the narrow cavities so as to have communication through the intervening scar tissue. The drill holes become filled with blood and later with granulation tissue, which contain the particles of bone dust. The more channels there are, the more likelihood there is of the development of the embryonic connective tissue necessary to callus formation. If the motor speed is cut down by the use of a rheostat, it is unnecessary to use any cooling solution. If a drill should break, the broken portion should be removed.

The operation is incomplete if adequate means are not taken to allow the fractured fragments to be jammed together in their subsequent immobilized state. For example, in a fracture of both bones of the leg, a united fibular fracture may prevent the jamming together of the fragments of the tibia. This problem can be solved by an oblique osteotomy of the fibula.

After the bone has been properly drilled, simple closure is effected. The part is then properly immobilized, as after a fresh fracture, and with as much care. A well-fitting, non-padded plaster-of-Paris cast is applied, to which a walking caliper is added after a week or ten days. The functional method of treatment, as described by Böhler, can then be adopted with profitable result. In the upper extremity, the cast or Roger Anderson fixation may be used.

Subcutaneous Bone-Drilling

In this method, no incision is made. The fracture site is defined. A little above the fracture site, a slim drill is pushed through the skin against the dense bone, and the drill holes are made in somewhat the same manner as already described. Similarly, the wire drill is pushed through the skin a little below the fracture site, and the same procedure followed at an angle to the previous drill holes. If a small nick is made in the skin, the operator will find that the drill will cause much less soft-tissue reaction. If such a nick is not made in the skin, the drill should be constantly sprayed with a solution of water or saline so as to prevent burning of the skin, which may form a nidus for subsequent infection. All in all, this latter method is not favored. In order to be certain that the drill is passing across the fracture site, a roentgenogram is taken, with sterile technique, following introduction of the drill. This roentgenogram should, of course, be taken in two views.

ANALYSIS OF CASES

Certain points may be of interest in the study of the twenty-five consecutive cases on which this report is based. In age, the patients ranged from twenty to fifty years. Eighteen were between twenty and thirty years, five were between thirty and forty years, and two were between forty and fifty years. All but two of the patients (one colored and one Chinese) were white. The time interval prior to operation varied. It was three months in one patient, four months in five patients, four and one-half months in three, five months in five, five and one-half months in five, six months in five and seven months in one patient. The parts involved, types of accident and previous treatment were as follows:

PARTS INVOLVED

	No. of Patients
Right tibia	6
Left tibia	11
Right femur	3
Left femur	2
Right carponavicular	1
Right radius, lower third	1
Left clavicle	1

CAUSE OF INJURY

	No. of Patients
Struck by car	5
Airplane accident	2
Falls of various types	5
Automobile accidents, patients riding	8
Wrestling	2
Motorcycle accident	1
Gunshot wound	1
Softball	1

TYPES OF TREATMENT PREVIOUS TO ADMISSION

	No. of Patients
Closed reduction with application of plaster-of-Paris cast	12
Closed reduction with application of Kirschner wire (extension)	7
Closed reduction with insertion of Steinmann pins	3
Roger Anderson method and plaster-of-Paris cast	1
Open reduction with fixation by vitallium screws	1
Thomas splint with Pearson attachment, skin traction	1

Open reduction and wire fixation was done on one of the cases three weeks after closed reduction and application of cast had failed to correct the deformity.

FIG. 3-A

Delayed or non-union, five months after fracture.

FIG. 3-B

One month after drilling.

FIG. 3-C

Posterior view, six weeks after drilling.

FIG. 3-D

Ten weeks after drilling, showing good union.

Several complications were encountered. In one patient refracture occurred at the site of drilling, eight weeks following operation, after he had been walking for a week with the aid of a brace which he removed in order to go swimming. There was ultimate union, however. In another instance, x-ray examination three months after drilling revealed no bony union, and bone-grafting was mistakenly decided upon. At operation, the site of the former drilling was found to be clinically firm and united, but a few other drill holes were made to further stimulate healing. This patient returned to duty four weeks after the last operative procedure. In one case, a pressure sore developed, because of some slight angulation of the fragments. This was due to lack of attention in the application of the cast. The cast was removed, the pressure sore treated for a short period of time, and then a walking cast was reapplied. There was no bone infection, and the ultimate result was excellent union of the fracture. In two cases, union of only a portion of the fracture developed, and drilling was done a second time.

RESULTS AND CONCLUSIONS

All cases, except one, showed bony union, both clinically and roentgenographically. The average duration for the development of union after drilling was eight weeks. The shortest period was three weeks (after fracture of a clavicle), and the longest was five months. The patients were up and around in a walking cast a week or ten days after operation. There were no postoperative infections.

Attention is again focused upon an old method, very little used, for the treatment of delayed union of fractures. The operation is comparatively simple, carries with it little potential danger, and offers a high incidence of success in bringing about complete union, clinically and roentgenographically. It is intended for delayed union and not for definitely established non-union.

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NOTE: Since this article was written, five additional cases of delayed union have been treated by bone-drilling, and solid bony union, as evidenced clinically and roentgenographically, has resulted in the average time.

DELAYED UNION IN FRACTURES OF THE TIBIA AND FIBULA

BY M. ALBERT, M.B., F.R.C.S., ENGLAND

From the Ministry of Pensions Hospital, Liverpool

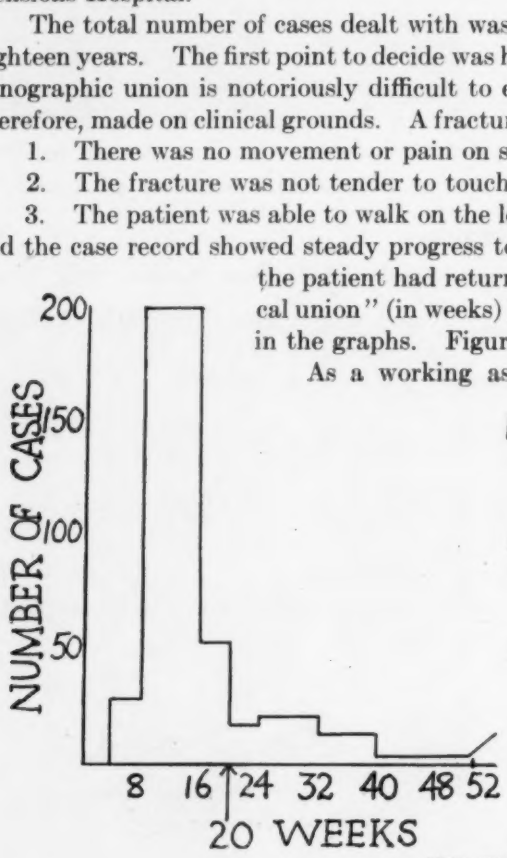
The question of slow union in fractures of the leg has been much under discussion lately. Working in a Ministry of Pensions Hospital, the author has been much impressed by the large number of these cases which have been admitted, and it appeared profitable to see if some of the views recently put forward could be substantiated. To do this, it was necessary to analyze the results in a fairly large number of cases treated at first-class fracture centers. These were taken from:

1. Two General Hospitals—one voluntary, the other municipal—where the clinics had been established long before the War, and have continued to function practically unchanged since.
2. Four centers established during wartime.
3. Cases under the care of Prof. T. P. McMurray and the author in a Ministry of Pensions Hospital.

The total number of cases dealt with was 395, all occurring in adults over the age of eighteen years. The first point to decide was how to determine the time of union. Roentgenographic union is notoriously difficult to estimate and agree upon; the decision was, therefore, made on clinical grounds. A fracture was taken to be "clinically united" when:

1. There was no movement or pain on straining the fracture;
2. The fracture was not tender to touch;
3. The patient was able to walk on the leg without the support of splints or plaster, and the case record showed steady progress to proved roentgenographic consolidation or the patient had returned to work. On this basis, "time of clinical union" (in weeks) has been plotted against "number of cases" in the graphs. Figure 1 shows all cases.

As a working assumption from inspection of this graph,



ALL CASES

FIG. 1

Clinical union in less than twenty weeks:
282 cases (71 per cent.)
Delayed union:
113 cases (29 per cent.)

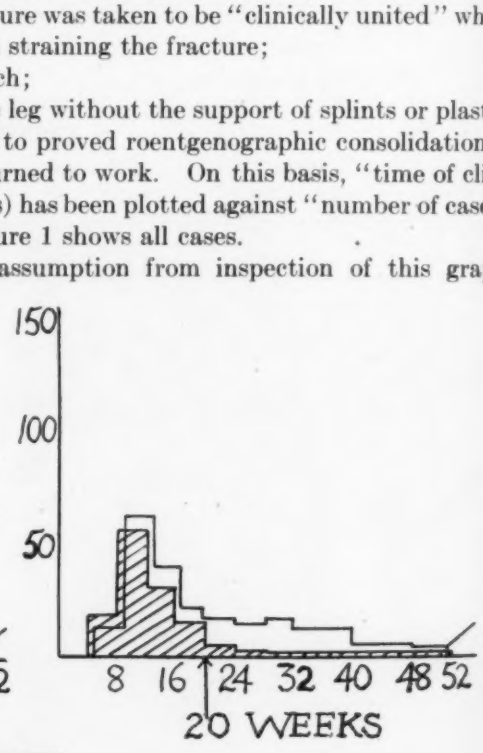
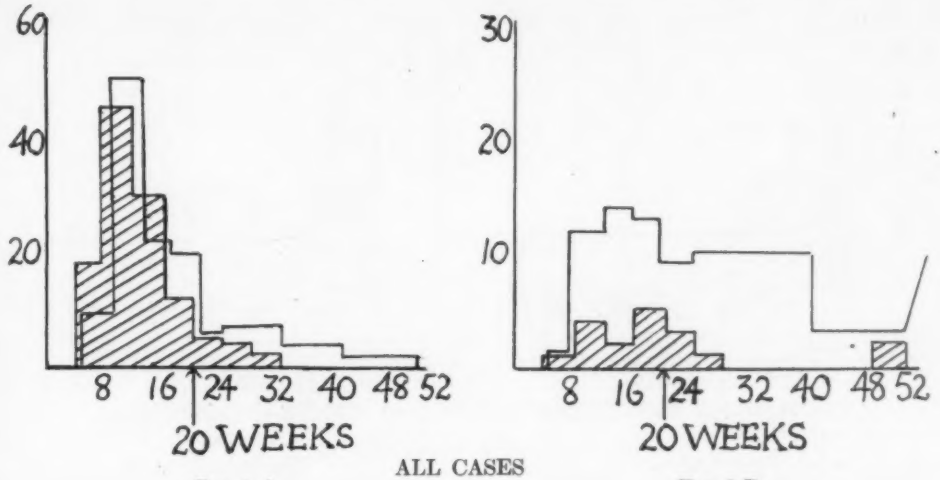


FIG. 2

Clinical union in less than twenty weeks:
Prewar (shaded): 120 cases (85 per cent.)
Wartime (white): 162 cases (64 per cent.)
Delayed union:
Prewar (shaded): 21 cases (15 per cent.)
Wartime (white): 92 cases (36 per cent.)



ALL CASES

FIG. 3-A

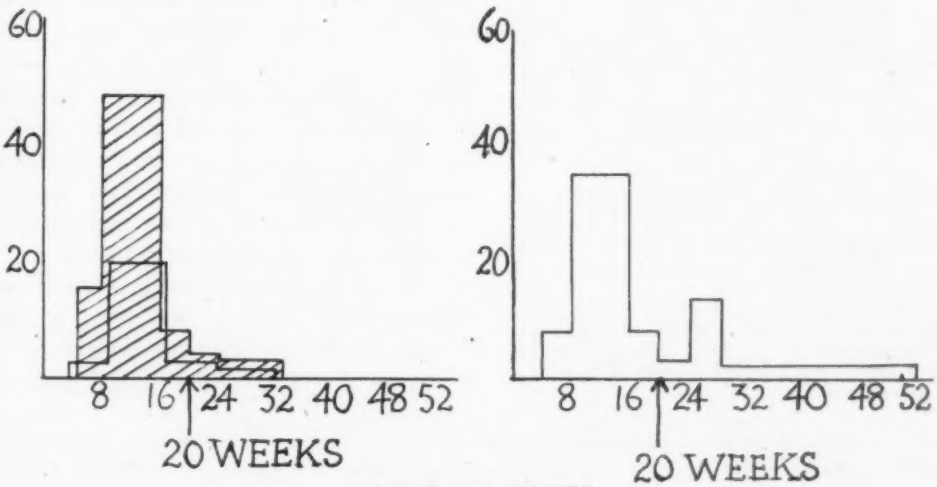
Simple fractures.
Clinical union in less than twenty weeks:
Prewar: 108 cases (89 per cent.)
Wartime: 120 cases (77 per cent.)
Delayed union:
Prewar: 13 cases (11 per cent.)
Wartime: 35 cases (23 per cent.)
Shaded area: prewar cases.

FIG. 3-B

Compound fractures.
Clinical union in less than twenty weeks:
Prewar: 12 cases (60 per cent.)
Wartime: 42 cases (42 per cent.)
Delayed union:
Prewar: 8 cases (40 per cent.)
Wartime: 57 cases (58 per cent.)
White area: wartime cases.

twenty weeks was taken as a dividing line between "normal" and "delayed" or "slow" union. On this assumption, 282 cases had united by twenty weeks, and 113 (29 per cent.) were delayed.

Is there any delay in the rate of union in wartime? If so, what are its causes? If all cases are considered, Figure 2 shows a definite increase in slow union in wartime. Of 141 prewar cases, twenty-one (15 per cent.) were delayed; of 254 wartime cases, ninety-two (36 per cent.) were delayed. This increase is true of both simple and compound fractures (Figs. 3-A and 3-B).



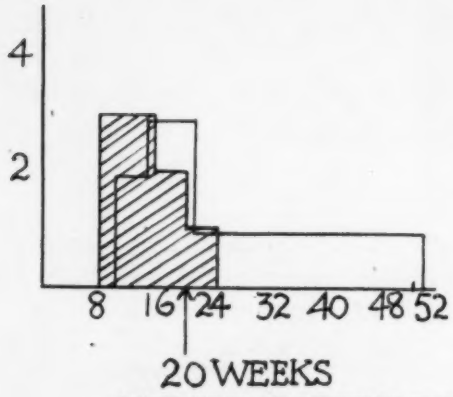
SIMPLE FRACTURES

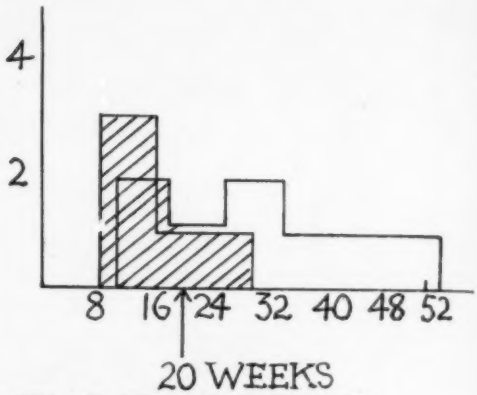
FIG. 4-A

Treated at General Hospitals.
Clinical union in less than twenty weeks:
Prewar: 108 cases (89 per cent.)
Wartime: 34 cases (94 per cent.)
Delayed union:
Prewar: 13 cases (11 per cent.)
Wartime: 2 cases (6 per cent.)
Shaded area: prewar cases.

FIG. 4-B

Treated at War Hospitals.
Clinical union in less than twenty weeks:
Wartime: 86 cases (72 per cent.)
Delayed union:
Wartime: 33 cases (28 per cent.)
White area: wartime cases.





COMPOUND FRACTURES TREATED AT GENERAL HOSPITALS

FIG. 4-C

Prewar cases.
Clinical union in less than twenty weeks:
Non-infected: 6 cases (67 per cent.)
Infected: 6 cases (55 per cent.)
Delayed union:
Non-infected: 3 cases (33 per cent.)
Infected: 5 cases (45 per cent.)

FIG. 4-D

Wartime cases.
Clinical union in less than twenty weeks:
Non-infected: 5 cases (83 per cent.)
Infected: 3 cases (50 per cent.)
Delayed union:
Non-infected: 1 case (17 per cent.)
Infected: 3 cases (50 per cent.)

Shaded area: non-infected cases. White area: infected cases.

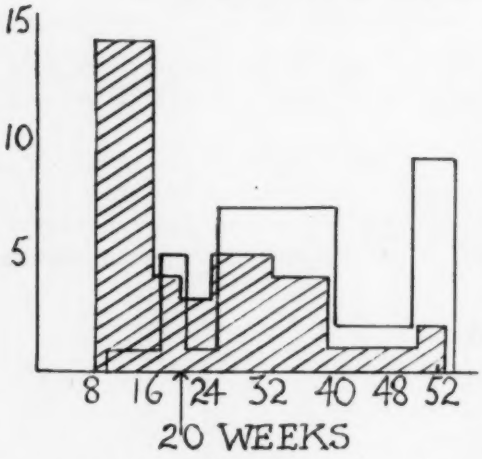


FIG. 4-E

COMPOUND FRACTURES TREATED AT WAR HOSPITALS

Non-infected: Clinical union in less than twenty weeks: 26 cases (54 per cent.). Delayed union: 22 cases (46 per cent.)
Infected: Clinical union in less than twenty weeks: 8 cases (21 per cent.). Delayed union: 31 cases (79 per cent.)
Shaded area: non-infected cases. White area: infected cases.

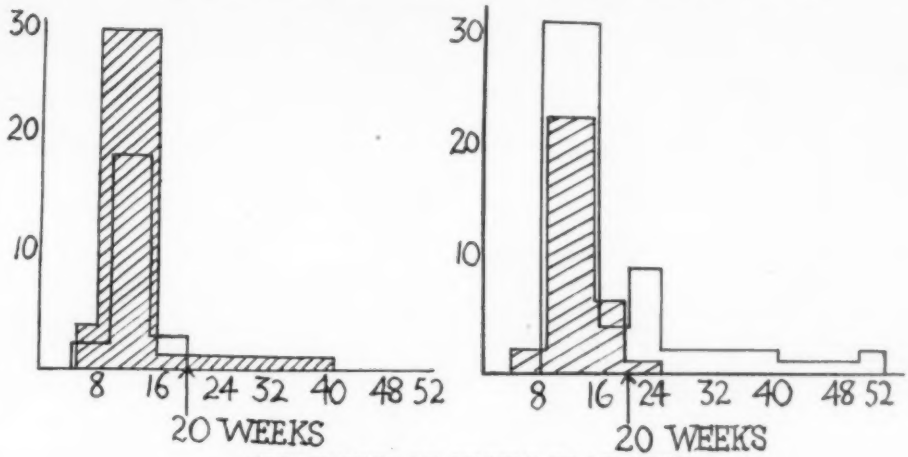
The second question requires more careful consideration. In the General Hospitals, the results before and during the War show no appreciable increase in the occurrence of delayed union in simple, compound infected, or compound non-infected fractures. It is probable, therefore, that such factors as dietary restrictions, lack of ventilation in the blackout, *et cetera*, do not play a paramount part in delaying union, and that the cause must be sought elsewhere. Also, in this group of cases taken as a whole, it is seen that delay in simple fractures occurs in less than 10 per cent.; in compound non-infected fractures, in less than 27 per cent.; and in compound infected fractures (that is, those showing definite evidence of bone necrosis such as sequestration) in about 50 per cent.

When the results in the War Hospitals are compared (Figs. 4-A and 4-B), we find:

1. A definite increase in delayed union in *simple* fractures (thirty-three cases or 28 per cent.).

2. A definite increase in the *number* of compound cases of both types, but not in the *relative proportion* of infected to non-infected cases. In the General Hospitals, there were seventeen infected (53 per cent.), and fifteen non-infected; and in the War Hospitals, thirty-nine infected (45 per cent.), and forty-eight non-infected.

3. A definite increase in delayed union in both infected and non-infected cases. In General Hospitals, eight cases (47 per cent.) of the infected group showed delay; and in War Hospitals, thirty-one cases (79 per cent.). In General Hospitals, four cases (27 per cent.) in the non-infected group showed delay; and in War Hospitals, twenty-two cases (46 per cent.).



TREATMENT OF SIMPLE FRACTURES

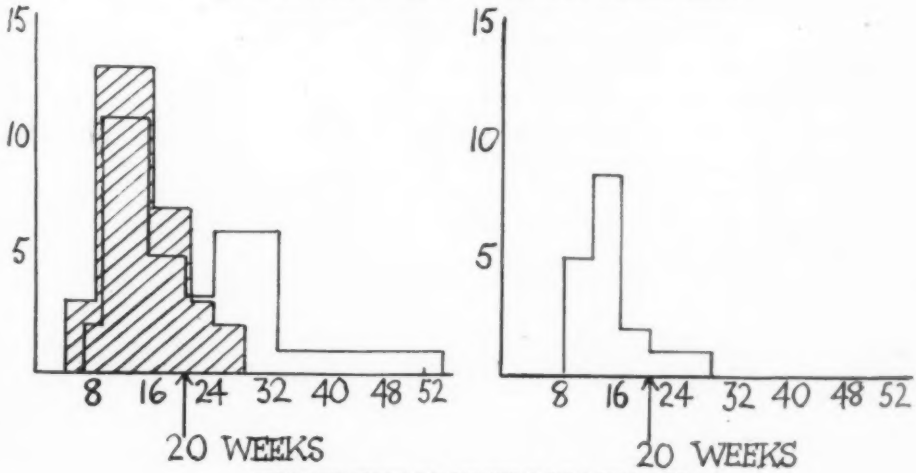
FIG. 5-A

Manual reduction and padded plaster.
Clinical union in less than twenty weeks:
Prewar: 44 cases (96 per cent.)
Wartime: 32 cases (100 per cent.)
Delayed union:
Prewar: 2 cases (4 per cent.)
Wartime: 0 cases (0 per cent.)

FIG. 5-B

Manual reduction and unpadded plaster.
Clinical union in less than twenty weeks:
Prewar: 36 cases (92 per cent.)
Wartime: 55 cases (77 per cent.)
Delayed union:
Prewar: 3 cases (8 per cent.)
Wartime: 16 cases (23 per cent.)

Shaded area: prewar cases. White area: wartime cases.



TREATMENT OF SIMPLE FRACTURES

FIG. 5-C

Skeletal traction.
Clinical union in less than twenty weeks:
Prewar: 28 cases (78 per cent.)
Wartime: 18 cases (50 per cent.)
Delayed union:
Prewar: 8 cases (22 per cent.)
Wartime: 18 cases (50 per cent.)

FIG. 5-D

Thomas splint.
Clinical union in less than twenty weeks:
Wartime: 15 cases (94 per cent.)
Delayed union:
Wartime: 1 case (6 per cent.)

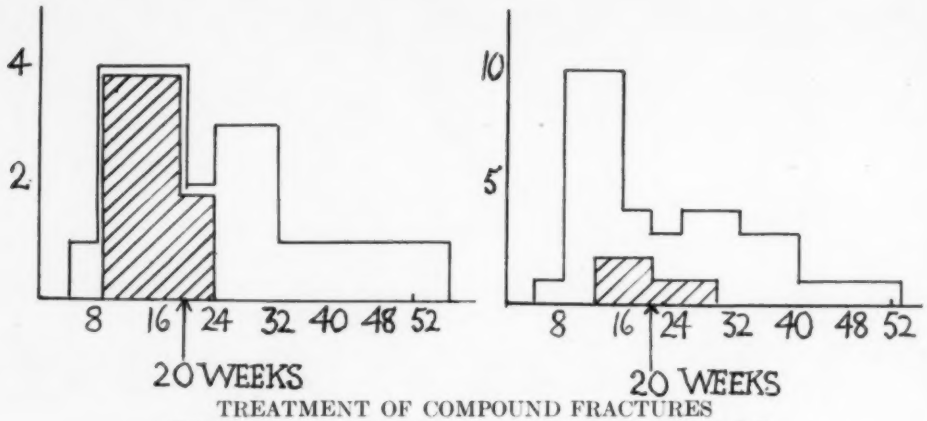
Shaded area: prewar cases. White area: wartime cases.

On these grounds, one is forced to the conclusion that the effective factors are concerned with the conditions of treatment. An analysis of some of these factors is now presented.

1. *Simple Fractures* (Figs. 5-A to 5-D)

The 276 simple fractures are classified according to treatment as follows:

A. *Manual reduction and the application of a long padded plaster cast.* Only two cases in a total of seventy-eight showed delay (3 per cent.); one united in thirty-two weeks, the other in forty weeks.



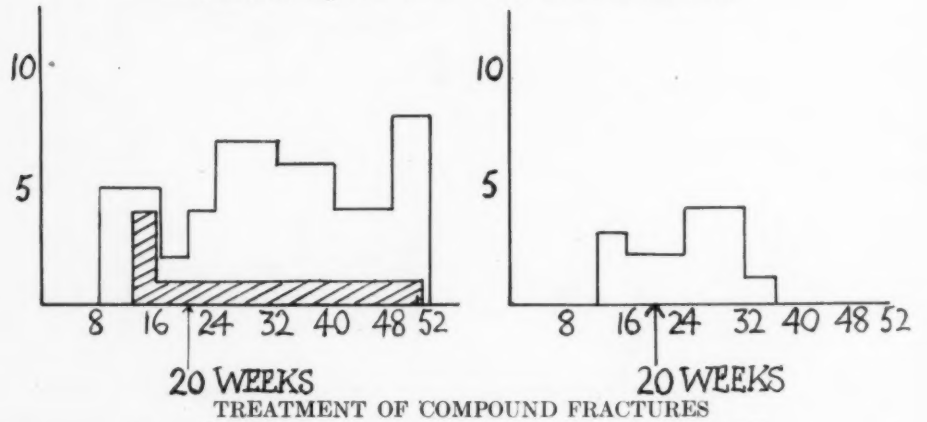
TREATMENT OF COMPOUND FRACTURES

FIG. 5-E

Manual reduction and padded plaster.
Clinical union in less than twenty weeks:
Prewar: 5 cases (83 per cent.)
Wartime: 9 cases (47 per cent.)
Delayed union:
Prewar: 1 case (17 per cent.)
Wartime: 10 cases (53 per cent.)
11 infected cases; 14 non-infected.
Shaded area: prewar cases.

FIG. 5-F

Manual reduction and unpadded plaster.
Clinical union in less than twenty weeks:
Prewar: 3 cases (60 per cent.)
Wartime: 18 cases (64 per cent.)
Delayed union:
Prewar: 2 cases (40 per cent.)
Wartime: 10 cases (36 per cent.)
17 infected cases; 16 non-infected.
White area: wartime cases.



TREATMENT OF COMPOUND FRACTURES

FIG. 5-G

Skeletal traction.
Clinical union in less than twenty weeks:
Prewar: 4 cases (44 per cent.)
Wartime: 10 cases (24 per cent.)
Delayed union:
Prewar: 5 cases (56 per cent.)
Wartime: 31 cases (76 per cent.)
23 infected cases; 27 non-infected.
Shaded area: prewar cases.

FIG. 5-H

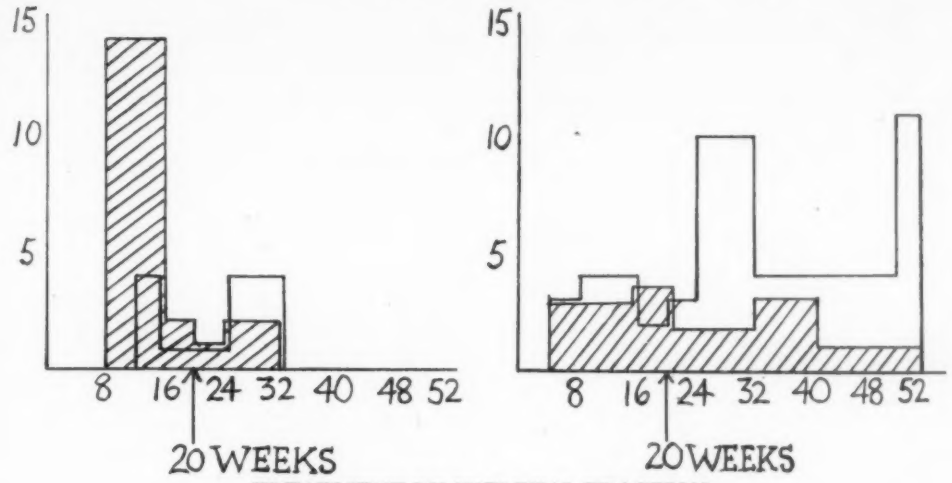
Thomas splint.
Clinical union in less than twenty weeks:
Wartime: 5 cases (45 per cent.)
Delayed union:
Wartime: 6 cases (55 per cent.)
5 infected cases; 6 non-infected.
White area: wartime cases.

B. *Manual reduction and the application of a long unpadded plaster.* In 110 cases, nineteen showed delay (17 per cent.). Sixteen of these occurred during the War, and only two of these sixteen were treated at the General Hospitals.

C. *Skeletal traction including os calcis pin, tibial pin, and distraction in reducing apparatus.* In seventy-two cases, twenty-six (36 per cent.) showed delay.

D. *Thomas splint with skin extension.* In sixteen cases, one showed delay (6 per cent.).

It may be suggested that Group C (skeletal traction) was one in which reduction was very difficult, and, therefore, union was delayed. However, it must be noted that one of the General Hospitals employed the padded plaster in all of sixty cases treated there, many of which were oblique and comminuted fractures, without resort to skeletal traction, yet



TREATMENT BY SKELETAL TRACTION

FIG. 6-A

"Short" skeletal traction.
Clinical union in less than twenty weeks:
Simple fractures: 28 cases (78 per cent.)
Compound fractures: 4 cases (67 per cent.)
Delayed union:
Simple fractures: 8 cases (22 per cent.)
Compound fractures: 2 cases (33 per cent.)
Shaded area: simple fractures.

FIG. 6-B

"Long" skeletal traction.
Clinical union in less than twenty weeks:
Simple fractures: 18 cases (49 per cent.)
Compound fractures: 10 cases (23 per cent.)
Delayed union:
Simple fractures: 19 cases (51 per cent.)
Compound fractures: 34 cases (77 per cent.)
White area: compound fractures.

there was only a very small incidence of delayed union. It may be concluded that in simple fractures, manual reduction and the long padded cast is the method of choice (considering time of union), and that the employment of skeletal traction is to be avoided.

2. *Compound Fractures* (Figs. 5-E to 5-H)

The treatment of the 119 compound fractures is analyzed as follows:

E. *Manual reduction and padded plaster.* Of twenty-five cases, eleven showed delay (43 per cent.). The proportion of infected to non-infected fractures was eleven to fourteen (44 per cent.).

F. *Manual reduction and unpadded plaster.* Of thirty-three cases, twelve showed delay (36 per cent.). The proportion of infected to non-infected fractures was seventeen to sixteen (52 per cent.).

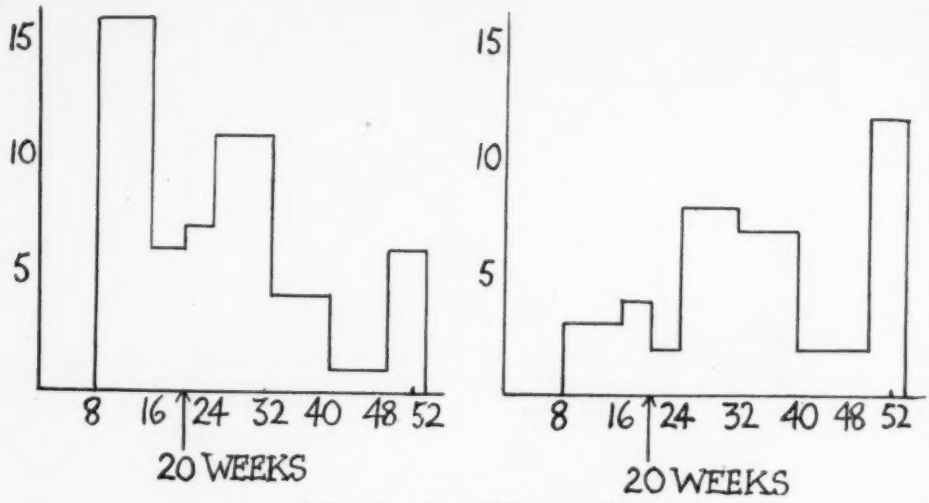
G. *Skeletal traction.* Of fifty cases, thirty-six showed delay (72 per cent.). The proportion of infected to non-infected fractures was twenty-three to twenty-seven (46 per cent.).

H. *Thomas splint.* Of eleven cases, six showed delay (55 per cent.). The proportion of infected to non-infected fractures was five to six (45 per cent.).

There does not appear to be any great difference in delay between the two methods of plaster fixation; probably "sepsis" or "no sepsis" is the determining factor. However, in the skeletal-traction group, delay occurred in 72 per cent. in spite of a practically identical sepsis rate. The group treated by the Thomas splint is too small to warrant any definite conclusions being drawn, although four of the five "delayed" cases had united by thirty-two weeks. Thus, in compound fractures, it would appear that either method of plaster fixation is satisfactory, but skeletal traction should be avoided.

3. *Skeletal Traction* (Figs. 6-A and 6-B)

Following this line of thought the cases in which skeletal traction was employed were divided into those in which traction was applied only for immediate reduction, when plaster was applied and the pin was removed (these are called "short" skeletal traction), and



EFFECT OF "DISTURBANCE"

FIG. 7-A

On simple fractures.
Clinical union in less than twenty weeks:
28 cases (42 per cent.)
Delayed union:
39 cases (58 per cent.)

FIG. 7-B

On compound fractures.
Clinical union in less than twenty weeks:
13 cases (25 per cent.)
Delayed union:
40 cases (75 per cent.)

those in which skeletal traction was applied continuously with or without plaster fixation, for periods ranging from a few days to several months ("long" skeletal traction).

Short skeletal traction (Fig. 6-A). Of thirty-six cases of simple fracture, eight (22 per cent.) showed delay; and of six cases of compound fracture, two (33 per cent.) showed delay.

Long skeletal traction (Fig. 6-B). Of thirty-seven cases of simple fracture, nineteen (51 per cent.) showed delay; and of forty-four cases of compound fracture, thirty-four (77 per cent.) showed delay.

It would thus appear that, although the use of short skeletal traction may occasionally be justifiable, continuous skeletal traction is a surgical sin. In this connection also, the bad results of distraction resulting from use of one of the commercial reducing machines should be noted. In seven cases (three simple, three non-infected, and one infected), one united in nine weeks, one united in twenty-six weeks, four required bone-grafting (at sixteen, twenty-one, twenty-two, and thirty-two weeks, respectively), and one

TABLE I

SITE OF FRACTURE IN TIBIA

Site	Simple			Compound		
	No. of Cases	No. Delayed	Per Cent. Delayed	No. of Cases	No. Delayed	Per Cent. Delayed
Lower third	65	7	11	22	12	54
Junction of middle and lower thirds	46	9	20	26	20	77
Middle third	143	27	19	54	26	48
Junction of upper and middle thirds	8	2	25	6	3	50
Upper third	14	3	21	11	4	36
Totals	276	48	17	119	65	54

showed fibrous malunion at sixty-five weeks, but united clinically in seven weeks after osteotomy and the application of a padded cast (Figs. 10-A and 10-B).

The case records leave no room for doubt that skeletal traction very often is synonymous with "overdistraction"; and the incidence of pin-track sepsis (five cases in 123, or 4 per cent.) and of stiff subastragalar joints is also by no means negligible.

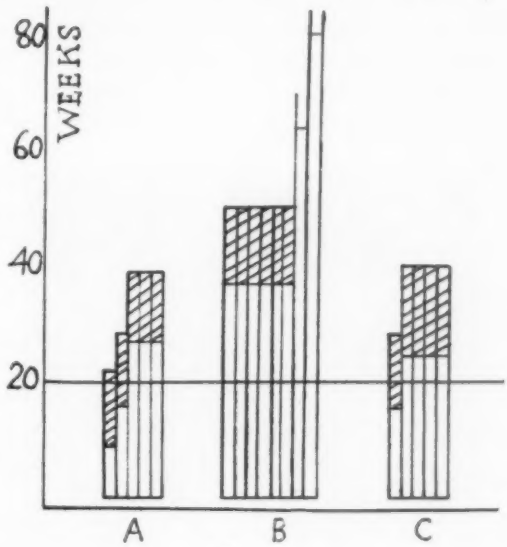


FIG. 8

Bone-graft cases.
Each small rectangle represents one case.
The shaded area indicates time after the bone-graft operation.
The open rectangle indicates failure to unite.
Group *A:* Simple fractures; Group *B:* Compound infected fractures; Group *C:* Compound non-infected fractures.

4. *Disturbance*

Another factor of extreme importance in the causation of delayed union is termed "disturbance". By this is meant the transfer of the patient from hospital to hospital, frequent changes of plaster with remanipulation, and cases where continuous skeletal traction was applied after manual reduction had failed (Figs. 7-A and 7-B). Of sixty-seven cases of simple fracture, thirty-nine (58 per cent.) showed delay; and in compound fractures, of fifty-three cases, forty (75 per cent.) showed delay. There can thus be no doubt that "disturbance" is not a good thing.

5. *Age*

The age of the patient did not appear to have any significant effect on the time of union. The patients were divided into three groups,—eighteen to thirty years, thirty to fifty years, and over fifty years. The proportion of delay in these groups was 18 per cent., 17 per cent., and 20 per cent., respectively, for simple fractures; and 54, 58, and 50 per cent. for compound fractures.

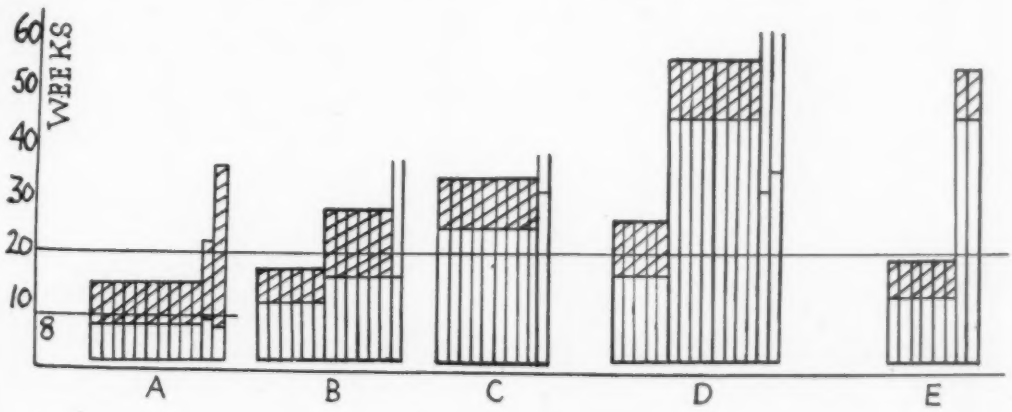


FIG. 9

Walking-caliper cases.
The shaded area indicates time in walking caliper.
Group *A:* Simple fractures for which the caliper was applied at or before eight weeks from the time of injury.
Group *B:* Simple fractures for which the caliper was applied from eight to twenty weeks from the time of injury.
Group *C:* Simple fractures for which caliper was applied after twenty weeks from the time of injury.
Group *D:* Compound fractures infected.
Group *E:* Compound fractures non-infected.

6. Site of Fracture

The site of fracture was grouped according to the position of the fracture in the shaft of the tibia. The results of the analysis are shown in Table I.

Some of the groups are too small from which to draw conclusions. On the whole, the site of the fracture does not appear to have any great effect except in one group,—compound fractures at the junction of the lower and middle thirds of the shaft of the tibia, where there is a very much higher proportion of delayed union (twenty cases out of twenty-six, or 77 per cent.). The cause of this high incidence of delay is not easy to eluci-

FIG. 10-A

FIG. 10-B

Fig. 10-A: Case 1. Fracture of the tibia and fibula sixty-five weeks after injury, showing fibrous malunion. The treatment had been continuous skeletal traction, then mechanical distraction for three weeks, followed by repeated plasters.

Fig. 10-B: Ten weeks after corrective osteotomy and application of a long padded plaster cast. The fracture was clinically united at seven weeks, and bony union was nearly complete at ten weeks.

FIG. 11-A

FIG. 11-B

Fig. 11-A: Case 2. Fracture of the tibia and fibula clinically and roentgenographically ununited at forty weeks.

Fig. 11-B: Bony union of the tibia was complete after sixteen weeks in walking caliper. After twelve weeks, the fracture was clinically solid and roentgenographic union was well advanced.

date, for poor blood supply and difficulty of reduction are factors which apply just as well to the consideration of simple fractures at this site. Note, however, that of the twenty-six compound fractures, ten were infected, and thirteen were treated by continuous skeletal traction (six infected and seven non-infected). This group is, in the author's opinion, too small for detailed analysis, but obviously merits further investigation, for these twenty cases of delayed union account for nearly one-third of all cases of delay in compound fractures.

7. *Weight-Bearing*

The influence of early and late weight-bearing, and of severity of the fracture could not be gauged from the case records of the various hospitals with a sufficient degree of accuracy to make their analysis worth while. These and other factors, such as the value or otherwise of early operation in difficult cases, must be left for others to determine.

TREATMENT

Although the previous discussion indicates that delayed union is largely preventable, the fact remains that it is occurring, and we are faced with the problem of how to treat it. It is, of course, possible to put forward the view that the successive application of walking plasters (padded or unpadded) will eventually lead to union. This may be true, but "eventually" may mean anything from six months to over three years, and this is a large slice of any man's life to be used for healing a broken leg. It may even mean "never". Both the surgeon and the patient are entitled to look for some more certain method of treatment. It is to be remembered that we are here discussing cases which are clinically ununited after twenty weeks.

The first and obvious answer is open operation, freshening the fracture surfaces, and internal fixation with a plate or bone graft. The results in bone-graft cases in this series (Fig. 8) were as follows:

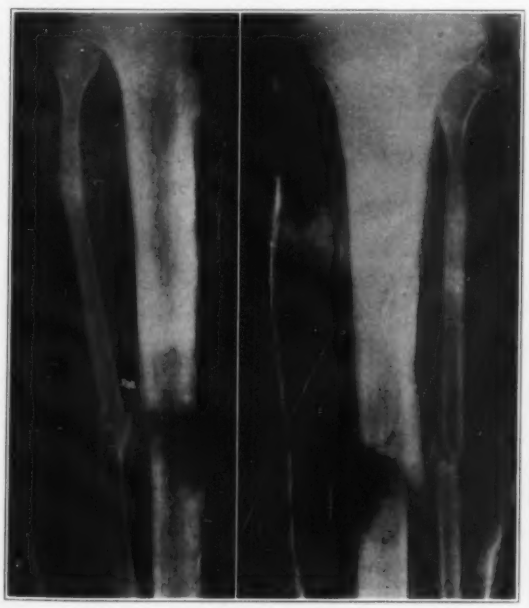


FIG. 12-A

FIG. 12-B

Fig. 12-A: Case 3. Roentgenogram taken in plaster shows ununited fractures of both bones at twenty-eight weeks. Discharging sinuses were present.

Fig. 12-B: Roentgenogram taken twenty-four weeks after application of walking caliper shows bony union. There was clinical union in less than fifteen weeks, with bony union well advanced and the wound healed.

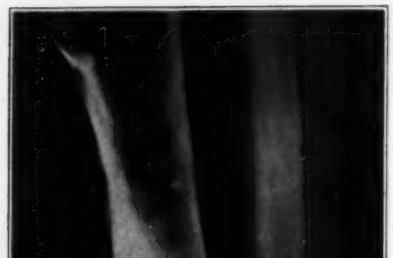


FIG. 13

Case 4. This case shows complete sclerosis of the bone ends, with a definite gap,—a clinically established non-union of many years' duration. The walking caliper cannot be expected to stimulate union here.

Five simple fractures, eight compound infected, and five compound non-infected fractures were treated. Two of the compound infected group failed to unite after the operation, owing to sepsis. The average time for clinical union after operation was twelve weeks for simple fractures, and thirteen weeks for compound fractures. Even this small number of cases suggests that the method is not quite devoid of risk, although in the absence of a recurrence of sepsis the risk is small.

Many years ago, Hugh Owen Thomas demonstrated a simple method of treatment which is now advocated by McMurray. This consists in the use of a walking caliper. It must be so constructed that the body weight is taken by the ischial tuberosity sitting on a padded leather ring. This is supported by two side irons fixed in a double round socket in the heel of the boot. The appliance must be worn day and night continuously. For this reason a pair of boots with felt tops is provided, and these are made so that there is no seam at the back to chafe the heel. A leather kneecap and an ankle strap, both fastened with buckles, fix the limb; and at the back, a long leather apron, extending from mid-thigh to well below the level of the fracture, ensures adequate support to the fragments. An ordinary sock is worn. Sores on the foot are prevented by gently removing the boot and sock each day, washing the foot and carefully drying and powdering it. This method of treatment is not recommended as infallible, but it is surprising and gratifying to find it successful in a large proportion of cases (Figs. 11-A, 11-B, 12-A, and 12-B). There are certain obvious contra-indications,—the presence of too large a gap between the bone ends, poor apposition, and sclerosis of the bone ends closing off the medullary cavity (Fig. 13). In such cases, the sooner a bone graft is done the better. It is to be noted that these are really cases of established non-union. But in cases of slow union, the method has certain definite advantages. First of all, the presence of sepsis is no bar to its use; even should the fracture fail to unite, the use of the caliper has not wasted any time, because bone-grafting is not safe until long after sepsis has cleared up. In addition to this, it is possible for the patient to go back to light employment while awaiting the result of the treatment, and there is thus no particular need to hurry in discarding the caliper before roentgenographic union is complete. The results of this method of treatment are as follows (Fig. 9):

In the various clinics, the walking caliper was used in fifty-eight cases,—thirty-five simple and twenty-three compound fractures. At one of the clinics, the caliper was applied in twelve cases at or before eight weeks from the time of injury, following immobilization in a Thomas splint (Fig. 9, Group *A*, simple fractures). Ten of these united at an average time after injury of fourteen weeks (average time in caliper, seven weeks), the other two cases united at twenty-two and thirty-six weeks, respectively (the first had also a fracture of the shaft of the femur). These findings do not suggest that the early application of the walking caliper greatly delays union, as has been stated.

In thirteen simple fractures, the caliper was applied eight to twenty weeks after injury (Fig. 9, Group *B*); six of these united in less than twenty weeks from the time of injury (average seventeen weeks after injury, six weeks in the caliper). Six united after

twenty weeks from time of injury (average twenty-eight weeks after injury, twelve weeks in the caliper). One fracture failed to unite, owing to sclerosis of the bone ends.

In ten simple fractures, the caliper was applied after twenty weeks from the time of injury,—that is, delayed union had been established (Fig. 9, Group *C*). Nine united at an average time of thirty-four weeks after injury (eight and one-half weeks in the caliper). One failed to unite.

In five of the fifteen infected compound fractures, the caliper was applied in less than twenty weeks from the time of injury (Fig. 9, Group *D*). All united at an average of twenty-six weeks after injury (ten weeks in the caliper); of the remaining ten infected fractures in which the caliper was applied for delayed union (Fig. 9, Group *D*), eight united in the average time of fifty-six weeks after injury (eleven weeks in the caliper), and two failed to unite. These failures occurred in two patients who had suffered compound fractures of the femur and of the tibia and fibula in the same limb. Both had been treated by skeletal traction followed by plaster spicas and both had ununited double fractures at thirty-one and thirty-five weeks. The femoral fractures were treated by open reduction and vitallium plating, and immobilization in a Thomas splint for ten weeks, and then the patients were allowed up in the walking caliper. Neither tibia has united; one of the femora also has failed to unite.

In the eight non-infected compound fractures (Fig. 9, Group *E*), the caliper was applied in less than twenty weeks in six cases; these all united at an average time of nineteen weeks after injury (seven weeks in the caliper). The remaining two cases, in which the caliper was applied for delayed union, united at fifty-four weeks after injury, the patient having been in the caliper for nine weeks.

Thus the caliper was applied in twenty-two cases of delayed union, and was successful in nineteen of them, the average time in the caliper being nine and one-half weeks.*

What happens when the walking caliper is used?

1. The caliper is weight-relieving.
2. There is protection of the fracture from any sudden large stresses or strains, but it cannot be said that immobilization is 100 per cent. perfect.
3. Six to eight weeks after the application of the caliper in the cases which are going to do well, roentgenographic examination shows an increased deposition of callus, and the fracture feels clinically solid. It may still be tender.
4. Congestion and oedema of the leg occur; but pass off without special treatment when union is complete. (Compare Thomas's "ham and dam" and Bier's congestion.)

The type of case which does best in a caliper is the one where there is a definite "rock" at the fracture site, no bony union is shown in the roentgenogram, and repeated plasters in the previous three to six months have resulted in no appreciable progress either clinically or roentgenographically.

SUMMARY

The results as regards time of clinical union in 395 cases of fracture of the tibia and fibula in adults have been analyzed. The conclusions drawn are as follows:

1. There has been an increase in the incidence of delayed union during this War.
2. This is noticed mainly in the newly established clinics.
3. The increase is seen in both simple and compound fractures.
4. In the greater number of compound fractures, "disturbance" of the course of treatment and the use of continuous skeletal traction appear to be the chief factors causing this increase. Most of these factors are preventable.
5. Manual reduction and the application of a long padded plaster cast is the method of choice in the treatment of simple fractures, from the point of view of speed of union.

* Since this article was written, a further twelve cases of delayed union have been treated in the walking caliper, with success in ten of them; the other two required bone-grafting.

6. The merits of bone-grafting and of the application of the walking caliper in cases where delayed union is present are discussed. It is considered that the results in this series establish *prima facie* evidence for the use of the walking caliper in selected cases.

7. Certain points, for example, the high incidence of delay in compound fractures at the junction of the lower and middle thirds of the tibia, the effect of the severity of the fracture, the effect of early or late weight-bearing, and the merits of early operation in cases where difficulty is experienced in reduction, require further investigation.

The author wishes to thank Prof. T. P. McMurray for his great help and encouragement; those surgeons who have so kindly allowed the author access to their records; Mr. B. C. Cox for the photography; and the Director General of Medical Services, Ministry of Pensions, for permission to publish this paper.

FRACTURES OF THE OS CALCIS

Tripod-Pin-Traction Apparatus

BY EARL D. McBRIDE, M.D., OKLAHOMA CITY, OKLAHOMA

The contour and alignment of the os calcis is such that severely comminuted fractures of this bone require forces of traction in an oblique line, downward and backward in relation to the tibia and foot. The angulation and flattening deformity of the bone, as well as the impacted widening and shortening, are reduced by extension in a direction which simultaneously overcomes both heel-cord and plantar-muscle resistance. Böhler accomplished this through his screw-traction apparatus and pins,—one placed in the tuberosity of the os calcis and the other in the tibia. The tripod-pin method, described here, has been used since 1932. At first Kirschner wire and ordinary store-type small turnbuckles served the purpose. Since then, thread-bar and nut-traction tubes, used with Steinmann pins, six thirty-seconds of an inch by eight inches in size, have proved much more practical and efficient.

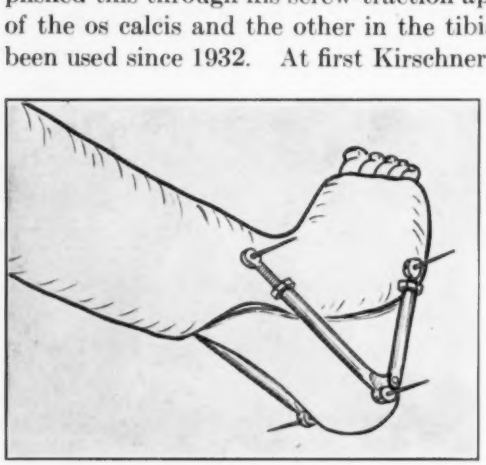


Fig. 1

Tripod-pin-traction apparatus.

The three pins are placed parallel and equal distances apart. One is placed in the tibia about four inches above the medial malleolus; one, through the base of the metatarsals; and the other, through the tuberosity of the os calcis.

Under general or local anaesthesia, the fragments are molded and reduced as well as possible by means of hand or vice pressure. Plaster, with ample padding, is applied from the toes to the knee. The foot is fixed in 10 degrees plantar flexion. The heel portion of the plaster is cut away to the level of the pins in the tibia and forefoot, but leaving these two pins firmly fixed in the plaster.

FIG. 2-A

Fracture of the os calcis before treatment.

FIG. 2-B

Fracture of the os calcis, reduced with the tripod-pin-traction apparatus.

The threaded-bar traction apparatus is then applied to the pins on each side of the foot. The tubes containing the threaded bar are hinged so that they have a common point of fixation to the heel pin. The plaster stabilizes the ankle with the tibia, so that traction between any two points in the tripod is supported in the opposing directions. Extension from the forefoot backward and from the tibia downward can be adjusted to the exact amount necessary for reduction. Furthermore, pronation or supination of the heel may be obtained by increasing traction on one side more than on the other.

When union is firm, in approximately four weeks, the apparatus and pins are removed, and a walking cast is applied.

NOTE: An earlier form of this apparatus was shown in the author's book, "Disability Evaluation. Principles of Treatment of Compensable Injuries", p. 463. (Philadelphia. J. B. Lippincott Co., 1936.)

A POSTERIOR APPROACH TO THE SHOULDER JOINT

BY MAJOR CARTER R. ROWE AND CAPTAIN LESTER B. K. YEE

Medical Corps, Army of the United States

Our interest in a surgical approach to the posterior aspect of the shoulder joint was stimulated by two cases of recurrent posterior dislocation of the shoulder. The problems were:

1. To expose adequately the posterior and inferior aspects of the shoulder joint.
2. To avoid injury to the suprascapular nerve as it courses around the suprascapular notch to supply the supraspinatus and infraspinatus.
3. To avoid injury to the axillary nerve and branches as they course around the humeral neck to supply the deltoid and teres minor.
4. To approach the posterior aspect of the shoulder joint along anatomical planes, thus minimizing injury to muscle tissue and supporting structures of the joint.

ANATOMY OF THE POSTERIOR ASPECT OF THE SHOULDER JOINT

The important anatomical structures involved in the surgical approach to be described are shown in Figures 1 and 2. Figure 1 shows the course of the suprascapular and axillary

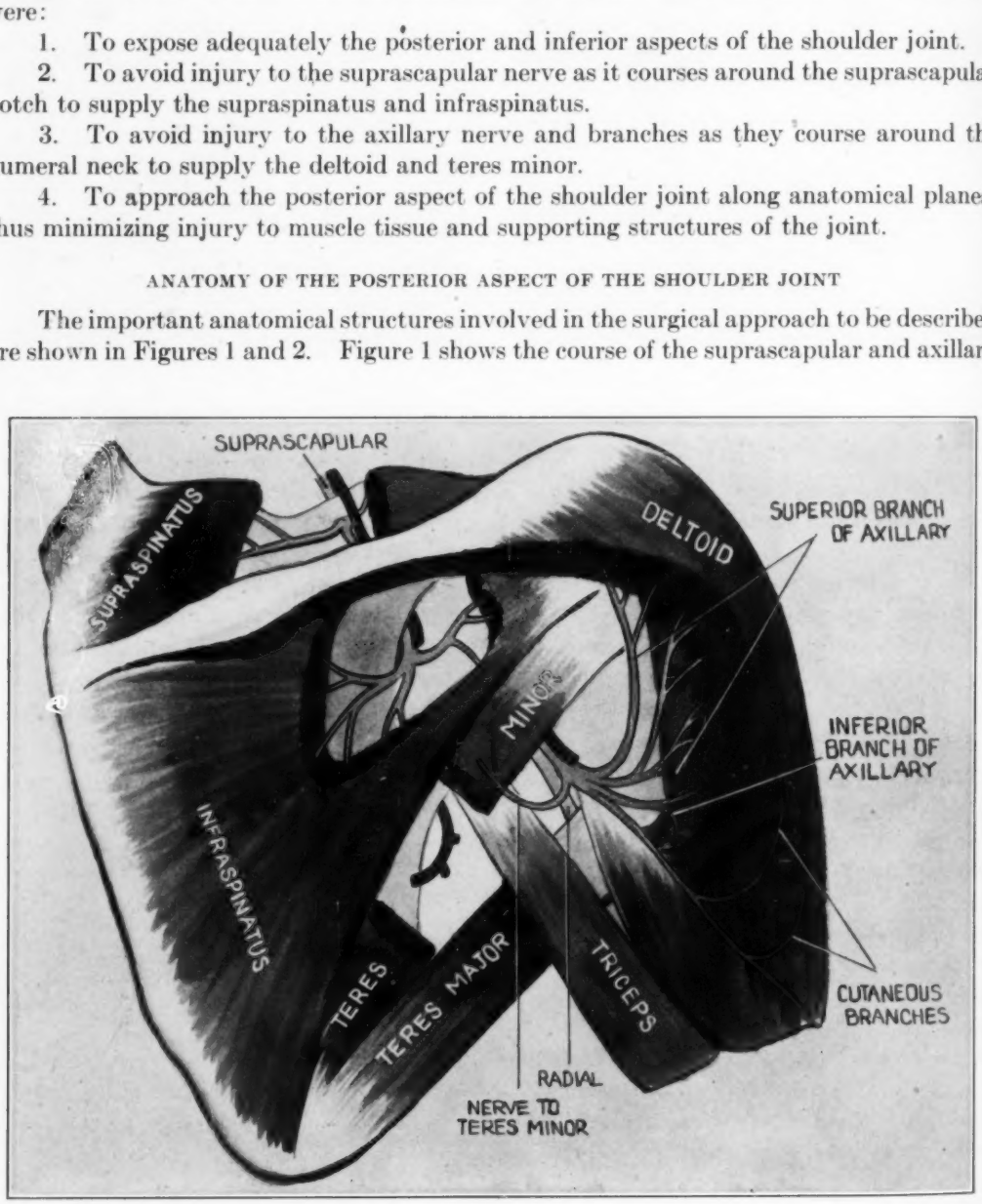


FIG. 1

The course of the suprascapular nerve and vessels is shown as they curve around the lateral border of the spine of the scapula and enter the infraspinatous fossa to supply the infraspinatus. It also shows the axillary nerve and vessels, as they wind around the surgical neck of the humerus to supply the teres minor and deltoid.

nerves and their relation to the posterior shoulder joint. Figure 2 illustrates the posterior shoulder "cuff" muscles, consisting of the supraspinatus, the infraspinatus, and the teres minor, all of which insert into the greater tuberosity of the humerus. The deltoid in this figure has been reflected, exposing the quadrilateral space through which runs the axillary nerve. It is noted that the quadrilateral space is bounded by the teres minor superiorly, the teres major inferiorly, the long head of the triceps medially, and the surgical neck of the humerus laterally.

THE SURGICAL APPROACH

The patient is placed face down on the operating table with both arms outstretched on arm boards. A folded blanket or pillow is placed under the chest on the side of operation. The patient's head is turned to the opposite side. The arm is prepared in the usual manner and covered with sterile stockinette.

The skin incision begins at the junction of the middle and inner thirds of the spine of the scapula, extends distally along the spine, and curves downward over the posterior aspect of the shoulder joint for a distance of four inches (Fig. 3).

The skin is retracted medially, exposing the posterior third of the deltoid (Fig. 4).

The deltoid attachment to the spine of the scapula is divided by sharp dissection, and is freed subperiosteally. Approximately one and a half inches from the medial border of the deltoid, the muscle is split downward for a distance of three inches. This should avoid injury to the nerve supply of the muscle. The triangular deltoid flap is turned laterally, exposing the infraspinatus and teres minor (Fig. 5).

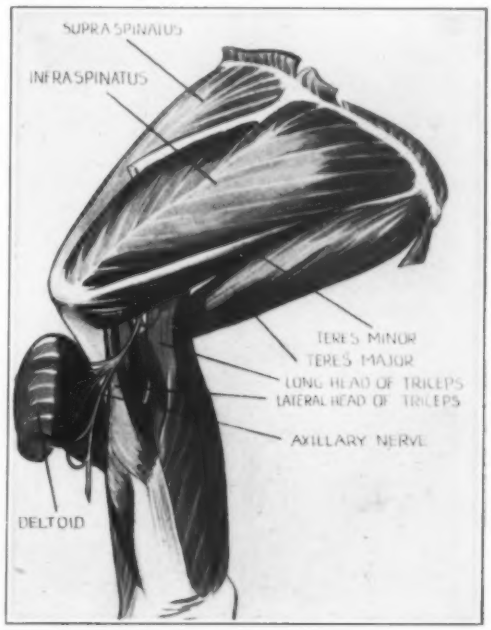


FIG. 2

Illustrating the posterior shoulder "cuff" muscles—the supraspinatus, the infraspinatus, and the teres minor, all of which insert into the greater tuberosity of the humerus—and the quadrilateral space, through which courses the axillary (circumflex) nerve and vessels. This space is bounded superiorly by the teres minor, inferiorly by the teres major, medially by the long head of the triceps, and laterally by the surgical neck of the humerus.

The infraspinatus and the teres minor are separated by blunt dissection. The infraspinatus is then freed from the underlying capsule by a blunt instrument, such as a periosteal elevator or a "joker". It is not so difficult to separate the posterior capsule from the infraspinatus as it is to separate the anterior capsule from the subscapularis. The tendinous attachment of the infraspinatus is then divided about half an inch from its insertion to the greater tuberosity of the humerus, and is retracted medially. The teres minor is retracted inferiorly, thus exposing the capsule of the posterior and inferior aspects of the shoulder joint (Fig. 6). It is important to keep the incision above the teres minor in order to avoid injury to the axillary nerve which passes through the quadrilateral space, located just beneath the teres minor as shown in Figure 2.

The capsule is inspected externally. The interior of the posterior and inferior aspects of the shoulder joint can then be adequately exposed by a vertical incision through the capsule (Fig. 7). In the two cases to be described, the pathological process found was a separation or lifting up of the capsular attachment just beyond the glenoidal labrum. Neither case demonstrated a complete through-and-through tear of the capsule. The

FIG. 3

The skin incision begins at the junction of the middle and inner thirds of the spine of the scapula, extends distally along the spine, and curves downward over the posterior aspect of the shoulder joint.

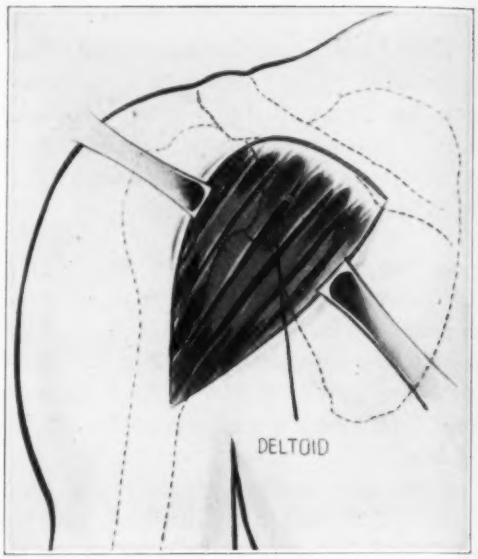


FIG. 4

Illustrating the exposure of the posterior deltoid after retraction of the skin medially.

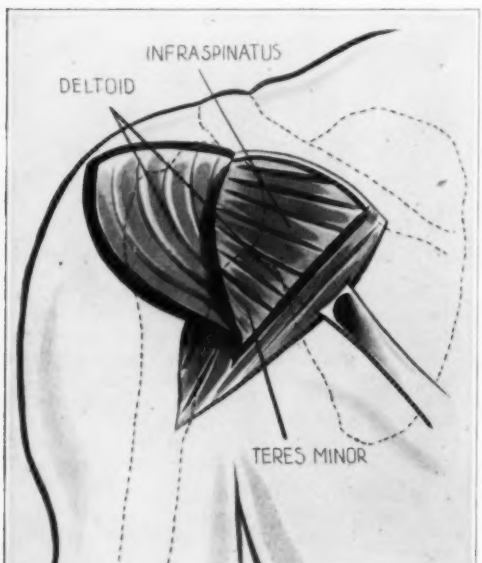


FIG. 5

The deltoid has been reflected subperiosteally from the spine of the scapula, and has been split in the line of its fibers for a distance of three inches only, in order to avoid damage to the nerve supply of this muscle (See Fig. 1). The medial one and a half inches of the deltoid is left attached to the spine of the scapula. The muscle flap is then turned lateralward exposing the infraspinatus and teres minor.

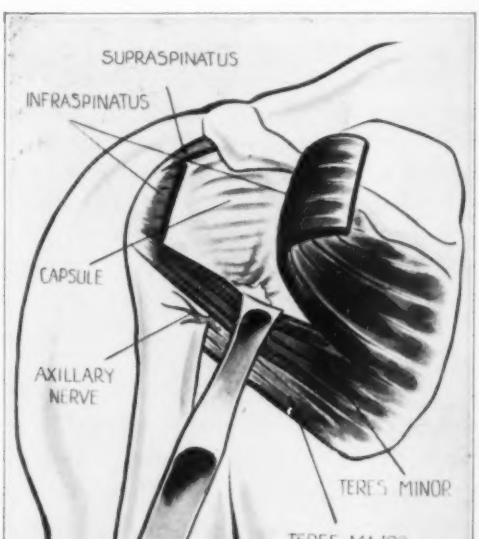


FIG. 6

The infraspinatus is separated from the teres minor by blunt dissection, and the tendinous insertion of the infraspinatus is divided by sharp dissection half an inch from its attachment to the greater tuberosity. The infraspinatus is then reflected from the posterior capsule of the shoulder joint. The teres minor is retracted inferiorly to expose adequately the posterior and inferior aspects of the shoulder joint. It is important to keep above the teres minor so as to avoid injury to the axillary nerve, which passes through the quadrilateral space located beneath the teres minor (See Fig. 2).

capsule was repaired by suturing the distal flap to the glenoidal rim with two or three mattress sutures placed through holes in the bone deep to the glenoidal labrum, similar to the

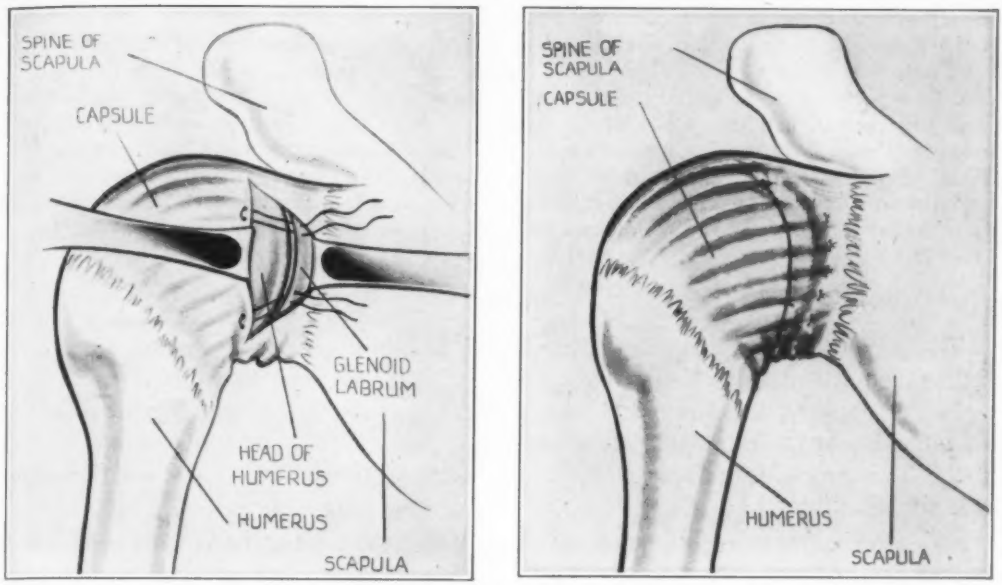


FIG. 7: Illustrating the vertical incision in the posterior capsule and exposure of the head of the humerus and posterior glenoid. In the two cases reported, repair was made by attachment of the capsule with mattress sutures through the glenoidal rim, and imbrication of the medial flap of the capsule over the attachment for extra support.

FIG. 8: Completion of the capsule repair by overlapping of the capsular flaps.

method described by Bankart[1]. For making these holes, we have used a small curved gouge, and we have found it far superior to the vulsellum forceps. The proximal or short flap is then overlapped and plicated by interrupted sutures for reinforcement.

CASE REPORTS

We have used the above approach in the following two cases of recurrent posterior dislocation of the shoulder.

CASE 1. The patient was a negro soldier of the Quartermaster Corps, twenty-two years old, who entered the Hospital on March 12, 1943, with a history of posterior subluxation of the shoulder. The initial injury had been an overarm thrust against his opponent's head, while boxing in 1940. Following the initial injury, the patient had had numerous posterior subluxations of the shoulder with pain, but he was always able to reduce the subluxations by exerting traction on his arm in flexion. This condition progressed to such an extent that the patient's shoulder would subluxate posteriorly with mere flexion and elevation of the arm. Physical examination showed a well-developed male, normal in all respects except the shoulder. The patient was able to demonstrate posterior subluxation of the head of the humerus by flexion and elevation of the arm. In this position, the head of the humerus could be felt to slip out of the glenoid fossa posteriorly. All laboratory studies, as well as anterior, posterior, and lateral roentgenograms of his shoulder were normal. On April 2, 1943, repair of the posterior capsule of the shoulder was carried out under general anaesthesia. At operation, it was noted that the shoulder could be subluxated posteriorly. The posterior capsule was found to be torn from its attachment beyond the glenoidal labrum, with a mild degree of erosion of the glenoidal rim. Plication of the capsule was performed by suturing the distal flap of the capsule to the glenoidal rim, as shown in Figure 7. The patient's postoperative course was uneventful. He was discharged to limited-service duty on May 28, 1943, and to full military duty on October 9, 1943. The patient had performed heavy labor as a prisoner, prior to discharge to full military duty.

CASE 2. This patient was a white soldier of the Army Air Corps, twenty-two years old, who entered the Hospital on July 22, 1943, because of recurrent posterior subluxation of the shoulder. His initial injury had been a fall on his outstretched arm in 1940. After the initial injury, the patient had been able to subluxate his shoulder posteriorly, with the arm in a position of flexion and elevation. He was able to replace his shoulder, except after the first dislocation, at which time traction had been necessary. He had been seen at another Army Hospital in this theater of operation, where a Nicola repair had been performed on April 7, 1943. Following discharge from the Hospital, the patient continued to have posterior subluxations of the

shoulder, similar in nature to the subluxations he had experienced prior to operation. His physical examination at this Hospital was normal, except that the patient was able to subluxate his shoulder posteriorly at will, by mere flexion and elevation of his arm. The head of the humerus could be felt to slip out of the glenoid fossa posteriorly. Laboratory studies, and anterior, posterior, and lateral roentgenograms of the shoulder were normal. On August 23, 1943, plastic repair of the shoulder-joint capsule was carried out under general anaesthesia. At operation, a moderate degree of erosion of the posterior and inferior surfaces of the glenoidal labrum was found. It was noted that the capsule was separated from its attachment to the glenoidal neck. Repair was performed by plication of the capsule with mattress stay sutures through the glenoidal rim, as in Case 1. This patient was discharged to full duty as a ground-crew mechanic on October 10, 1943.

SUMMARY

The advantages of this surgical approach to the posterior aspect of the shoulder joint, as demonstrated in two patients, are:

1. The approach follows structural planes and, therefore, diminishes blood loss and eliminates damage to important structures.

2. This procedure affords adequate exposure of the posterior and inferior aspects of the shoulder joint.

The authors wish to express their deep appreciation for the continued advice, criticism, and counsel of Lieutenant Colonel Edwin F. Cave, Chief of Surgical Service, throughout the progress of this study.

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SUBTALAR DISLOCATION

BY L. W. PLEWES, F.R.C.S., AND K. G. McKELVEY, M.R.C.S.
LUTON, BEDFORDSHIRE, ENGLAND

Complete dislocation at the subtalar joint is still so uncommon an injury as to merit report of two cases.

In 1811, Judey and Dufaurest each reported a case of this condition, and since then there has been a steady increase in the number of reports until, by 1937, 155 cases had been reported.

It appears that no age is immune, but by far the commonest period, according to Elward and Otell, is the third decade. It has been established that males are affected more often than females in the proportion of six to one [6], in spite of Delanoe's assertion that the accident occurs only in the adult male. Hugh Smith gives the range of ages as from ten to over sixty years.

All investigators agree that there are four groups according to the position of the foot in relation to the talus. The distribution of the 155 cases analyzed by Hugh Smith is as follows:

Direction	Cases	Per Cent.
Inward	87	56.1
Outward	52	33.5
Backward	10	6.5
Forward	6	3.9
Total	155	100.0

The figures of other investigators, notably those of Elward and Otell, and Delanoe, agree with Smith's analysis.

Although writers on this subject always refer to "subtalar" dislocation, it should be pointed out that the talonavicular joint is dislocated as well, but that the calcaneocuboid joint is intact.

It is of interest to consider the fate of the blood supply of the talus, upon which the most study seems to have been done by Sneed. His work consists of many roentgenograms, but little description, and all that he has succeeded in demonstrating is that there is a nutrient artery and numerous other small blood vessels. Most of these are probably severed with so severe a displacement; yet, after reduction, no necrosis develops. The

FIG. 1-A

FIG. 1-B

Case 1. Photographs showing subtalar dislocation.

FIG. 1-E

Roentgenogram taken from above showing the whole foot dislocated to the outer side, the talus still in its mortise, and the calcaneocuboid joint intact.

FIG. 1-D

Anteroposterior roentgenogram showing the outward displacement of the foot, and revealing several small fractures.

FIG. 1-C

Lateral roentgenogram showing complete subtalar dislocation.

blood supply must, therefore, have become re-established even after rupture of these arteries. Conwell and Alldredge are also of this opinion. The reason why aseptic necrosis does not follow this condition, and yet may occur after a slight crush fracture of the talus, is not apparent.

No definite method of treatment has yet been established, but many different methods have been advocated. Before 1920, open reduction or removal of the talus was advocated. Later workers have reported favorable results by both open and closed manipulative reductions —Smith and Delanoe by both open and closed reductions, and Elward and Otell by closed reduction.

CASE REPORTS

CASE 1. On August 16, 1940, a healthy male, aged twenty-seven years, was injured while taking physical training. He was running toward a fence and put his right foot forward against the fence both to stop himself and to start himself on the return journey. As he did so, his left foot slipped on the wet grass and his whole weight was transferred to his right foot, which crashed against the fence at an angle. As the patient weighed 175 pounds, the injury may be regarded as severe.

He was admitted to the Hospital within an hour, and gross deformity of the right foot was found (Figs. 1-A, 1-B, 1-C, 1-D, and 1-E). The skin on the inner and anterior aspect of the talus was stretched and white, but there was no other disturbance of circulation in the foot.

It was remarkable that such a gross deformity should have given rise to so little pain,—a feature commented upon by others. No drugs had been given before admission, and there was no shock present. The patient merely stated that it did not hurt much.

The accompanying photographs (Figs. 1-A and 1-B) and roentgenograms (Figs. 1-C, 1-D, and 1-E) are clear enough to make unnecessary the usual minute description of the

FIG. 2-A

Case 2. Anteroposterior roentgenogram showing dislocation of the foot to the inner side, with a large fragment torn off the posterior surface of the talus.

FIG. 2-B

Lateral roentgenogram showing the dislocation and the detached portion of the talus.

injury. They reveal not only the dislocation, but several small fractures of the posterior portion of the talus. The dislocation was to the outer side,—lateral dislocation (Group 2).

Under general anaesthesia, a Steinmann pin was inserted through the os calcis, and traction was applied by the Böhler leg-traction frame, as an attempt at manipulative reduction had failed. The reduction was done under fluoroscopic control. It was not until traction, to an amount at least double that required to reduce the usual fracture of the tibia and fibula, had been used for over one hour that the deformity began to yield. Even at this stage, manual attempts to finish the reduction were unsuccessful. With traction maintained, the Thomas wrench was used to gently force the head of the talus into place, and the reduction was completed easily by manual pressure on the outer side of the calcaneum.

A padded plaster cast was applied, and the leg was kept elevated on a Braun frame for three weeks. Then a new unpadded cast was used with a Böhler walking iron, and the patient was allowed to walk. The plaster was kept on for four months because recurrent subtalar pain was experienced.

Six months after the injury, the foot was normal in appearance, ankle movements were full, but there was very little subtalar movement. The disability was very slight.

Two years after the initial injury, function in the subtalar joint was 75 per cent. of normal. There is occasional pain in wet weather; but the foot is otherwise normal.

Case 2. On August 25, 1941, a man, aged thirty-five years and weighing 210 pounds, jumped three and one-half feet onto muddy ground, and suffered a twisting injury to his foot. In this case also there was a gross deformity. The dislocation was to the inner side,—medial dislocation, Group 1 (Figs. 2-A and 2-B). Again, there was remarkably little pain. He was not in shock, and preparations were made for a long and difficult reduction. Under general anaesthesia, however, the dislocation was reduced easily and without undue force. Roentgenograms revealed one large fragment of bone which had been torn off the talus.

A padded plaster was applied. Three weeks later all swelling had disappeared, and a walking plaster was put on, which was left on for two months. The man was then given an elastoplast support, and went back to work.

Fifteen months later he had no pain. The movements in the subtalar joint were complete. Power in this foot was as good as in the other.

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ACUTE ACROMIOCLAVICULAR DISLOCATION

A Simple Effective Method of Conservative Treatment

BY MAJOR IRVING WOLIN

Medical Corps, Army of the United States

Rupture of the coracoclavicular and acromioclavicular ligaments, resulting in upward dislocation of the outer end of the clavicle, is a frequent injury about the shoulder. Textbook descriptions of this condition [1, 2] state that the retentive appliance which is employed after reduction must maintain a constant upward push on the arm as well as downward pressure on the clavicle. However, since reduction is readily accomplished by a simple downward push on the prominent outer end of the clavicle, it would seem that an appliance which would continue to exert this downward pressure would be sufficient.

At the meeting of The American Orthopaedic Association held in Memphis in 1939, a splint devised many years previously by the late Dr. Hunkin of San Francisco was presented by Dr. Leonard Barnard of Oakland. So far as the author is aware, this has not been described in the literature. The original Hunkin method is as follows:

A webbing strap two inches wide and eight feet long, with a buckle attached to one end, is placed across

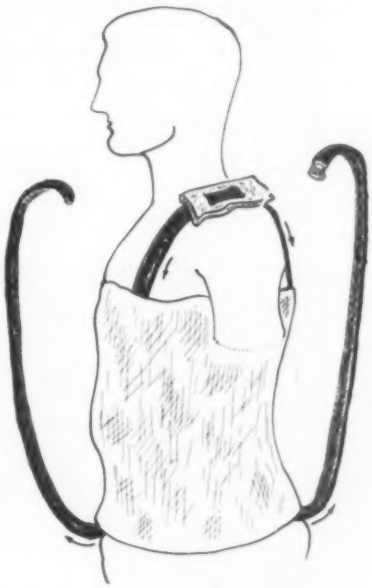

FIG. 1

Fig. 1: Method of applying simple torso cast which allows the free use of the upper extremity while maintaining constant downward pressure on the clavicle.

Fig. 2-A: Photograph of cast showing method of applying the strap.

Figs. 2-B and 2-C: Photographs showing cast and straps in place. The depression of the clavicle is maintained.

FIG. 2-A

FIG. 2-B

FIG. 2-C

the shoulder in the form of a long inverted U, and a felt pad is incorporated in the strap at the top of the shoulder. With the arm adducted, the elbow bent at 90 degrees, and the

FIG. 3-A

Case 1. G. P. B., on March 27, 1943, had a right acromioclavicular dislocation.

FIG. 3-B

March 28, 1943. This patient was treated by a spica cast.

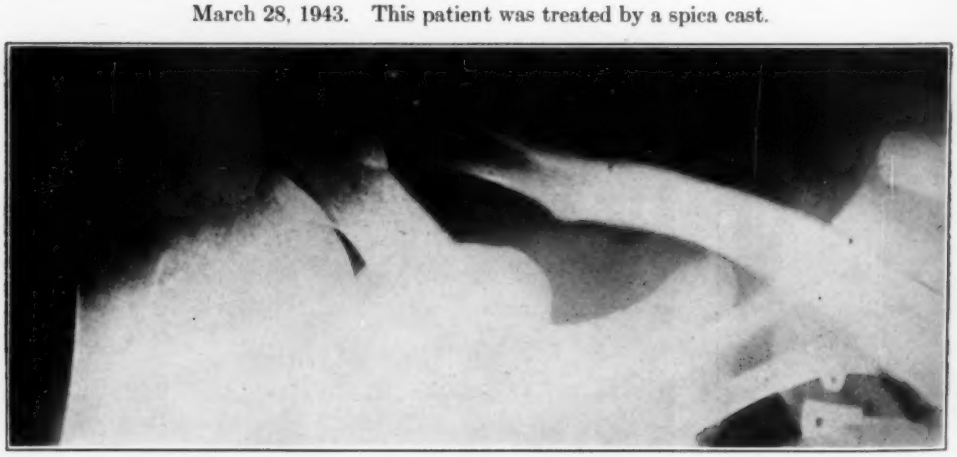

FIG. 3-C

April 30, 1943.

FIG. 4-A

Case 2. C. J. S., on April 10, 1943, had a right acromioclavicular dislocation.

FIG. 4-B

May 15, 1943. The patient was treated by the cast illustrated in Fig. 1.

forearm lying just in front of the body, a padded spica cast is applied. When the plaster is dry, the acromioclavicular dislocation is reduced by direct pressure on the clavicle and the strap is tightened in the following manner: After placing the felt pressure pad directly over the outer third of the clavicle, a strong downward pull is made on the front and rear portions of the strap, while at the same time the entire cast is pushed upward by an assistant. While tension is maintained, the strap is brought upward along the anterior and posterior aspects of the cast. The rear portion of the strap is brought over the shoulder directly in line with the felt pad and is buckled to the front portion at about the level of the nipple. A lateral check strap is added to prevent sideward motion of the suspending strap;

FIG. 5-A

Case 3. F. E. M., on May 15, 1943, had a left acromioclavicular dislocation.

FIG. 5-B

June 3, 1943. Patient was treated by torso-cast method illustrated in Figs. 2-A, 2-B, and 2-C.

FIG. 6-A

Case 4. F. L., on May 12, 1943, had a fracture of the outer end of the clavicle with upward angulation.

FIG. 6-B

June 10, 1943. The patient was treated with a simple torso cast.

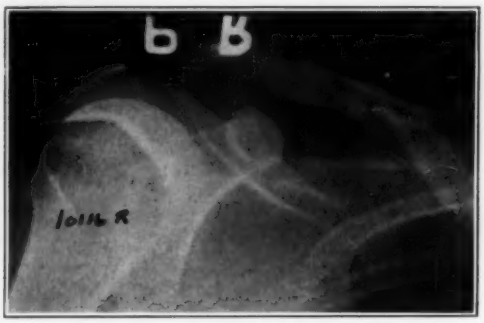

FIG. 7-A

Case 5. A. W., June 10, 1943, had a fracture near middle of clavicle with upward angulation.

FIG. 7-B

June 11, 1943. A simple torso cast has been applied.

windows are trimmed to expose the axilla, olecranon process, and medial epicondyle of the humerus. Immobilization must be maintained four to six weeks, during which time the patient must sleep on a 45-degree back rest. The strap is kept tight at all times.

The author has treated ten soldiers by this method. All returned to full duty after an average time of eight weeks, and all had normal contour and function of the joint.

Early in 1943, the author modified this method so as to eliminate the upward push on the arm. At first it was felt advisable to maintain adduction of the arm, but in the more recent cases, free motion of the entire upper extremity has been allowed. A simple torso cast is applied, incorporating the strap exactly as described in the Hunkin method (Figs. 1, 2-A, 2-B, and 2-C). So far as can be determined, in the three cases so treated, correction has been maintained just as well as in those treated by the spica cast.

CASE REPORTS

CASE 1. G. P. B., aged thirty years, sustained an acute right acromioclavicular dislocation March 27, 1943 (Fig. 3-A), when he fell while wrestling, and struck his right shoulder against the floor. A spica cast was applied, and the dislocation was reduced on the following day (Fig. 3-B). The cast was removed April 27, 1943, and the soldier returned to light duty May 1, 1943, with normal appearance and function of the shoulder. Figure 3-C shows the roentgenographic appearance on April 30, 1943.

CASE 2. C. J. S., aged twenty-six, dislocated his right acromioclavicular joint (Fig. 4-A) April 10, 1943, when he fell and struck his right shoulder against the ground. Corrective cast allowing free motion of the elbow was applied April 10, 1943. The cast was removed May 12, 1943, and the patient returned to duty May 17, 1943. The appearance of the shoulder was normal as were its motions.

CASE 3. F. E. M., aged twenty-four, dislocated his left acromioclavicular joint on May 15, 1943 (Fig. 5-A), when he slipped and fell, his left shoulder striking the ground. On May 16, 1943, a torso cast of the type shown in Figures 2-A, 2-B, and 2-C was applied. Reduction has remained satisfactory, even though free use of the shoulder and arm has been allowed. The latest roentgenogram was taken June 3, 1943 (Fig. 5-B). When the cast was removed, June 19, 1943, the acromioclavicular joint had normal contour and stability.

The same simple torso-cast method is also applicable to certain fractures of the clavicle with upward angulation (Figs. 6-A, 6-B, 7-A, and 7-B). It has also been used in one case of fracture of the medial end of the clavicle with subluxation of the sternoclavicular joint. In this case, the pressure pad was placed over the sternal end of the clavicle, and the suspension strap was directed downward and medialward.

Unfortunately, the author is unable to give suitable end results of these cases because of military exigencies. However, the author has seen personally several of the patients after eight or ten months, and they had excellent contour, stability, and function.

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A PRACTICAL HUMERUS SPLINT

BY CAPTAIN RANDALL W. HENRY

Medical Corps, Army of the United States

A simple, practical, effective humerus splint would certainly be an asset to the Army and to the industrial surgeon in the transportation and treatment of fractures in this region. Most orthopaedic surgeons agree that such a splint does not exist at the present time, that simple board splinting, a Velpeau bandage, or a sling is sufficient for transportation, and that a hanging cast or a plaster body spica surpasses all other types of external fixation. With these facts fully in mind, as well as the fact that in some of our theaters of operation, plaster is not practical, the author wishes to present a splint which he feels will be of definite value. The splint is presented, not with the idea that it will replace all other types of external fixation, but with the thought that it can be used to advantage in transporting patients with injuries to the humerus, and may prove of value in the subsequent treatment.

The splint provides powerful traction and countertraction, without endangering the involved areas; allows varying degrees of abduction; furnishes adequate fixation; is simple in construction and application; possesses no complicated gadgets or accessories; can be

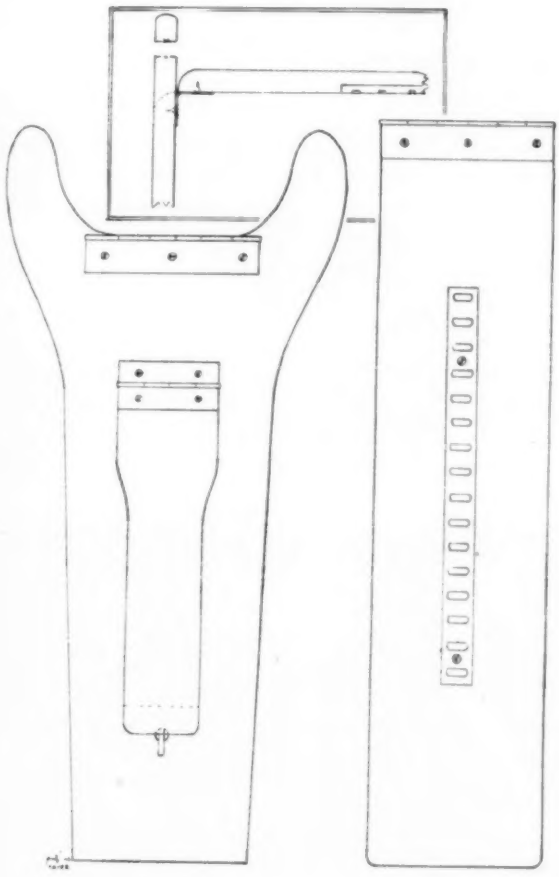

FIG. 1-A

FIG. 1-B

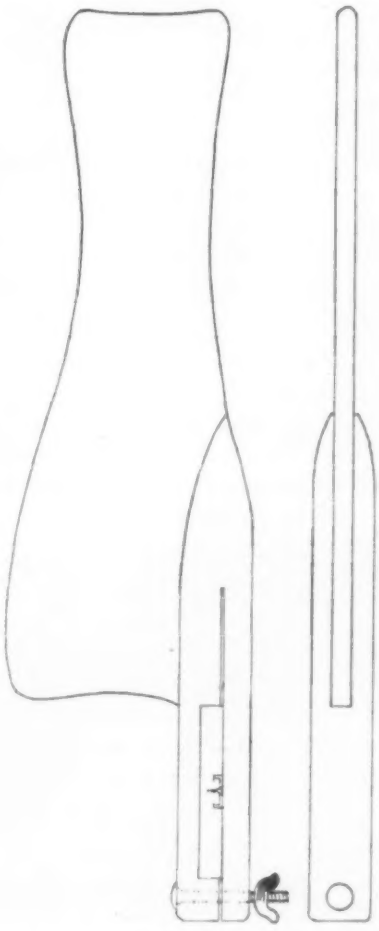

FIG. 1-C

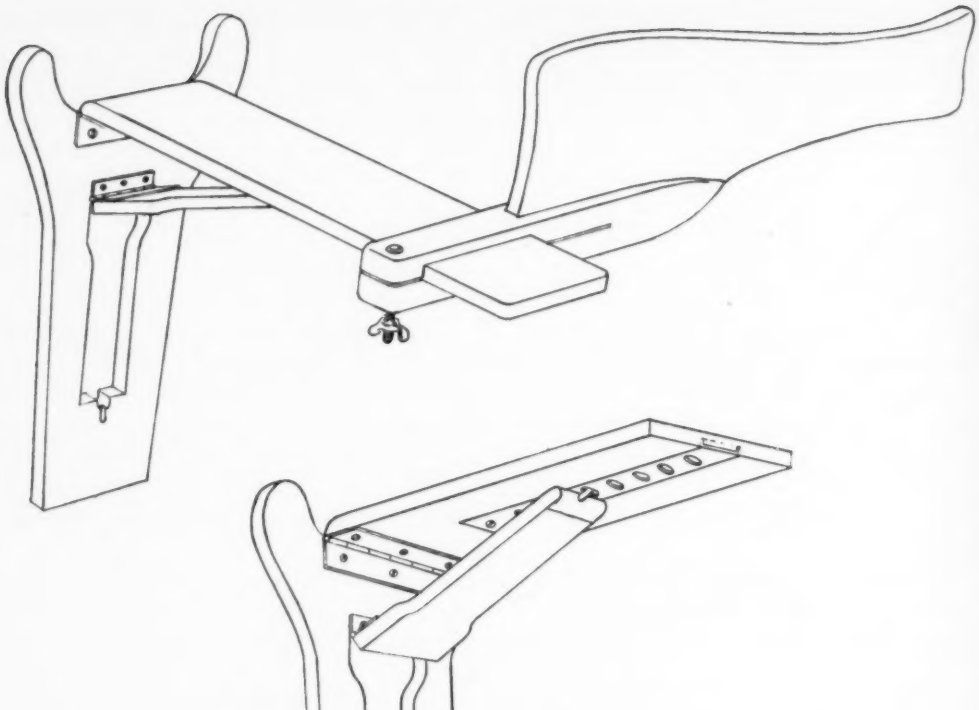

FIG. 2

used on either arm; is light in weight and compact; and is permeable to roentgen ray. The traction on the humerus is accomplished by pressure on the flexor surface of the forearm, in much the same manner as traction to the femur by pressure on the flexor surface of the leg is provided by the Pearson attachment to the Thomas splint. The amount of pressure necessary to overcome the pull of the muscles of the upper arm and shoulder is distributed over the entire area of the flexor surface of the forearm, minimizing the actual pressure per square inch.

Countertraction is obtained by a distributed pressure, about four inches wide, over the lateral wall of the thoracic cage. In this way pressure against the axilla is avoided.

Varying degrees of abduction are obtained by raising or lowering the horizontal board, which is held in place by a brace hinged to the vertical body board. This is easily adjusted and fixed in position by a ratchet device.

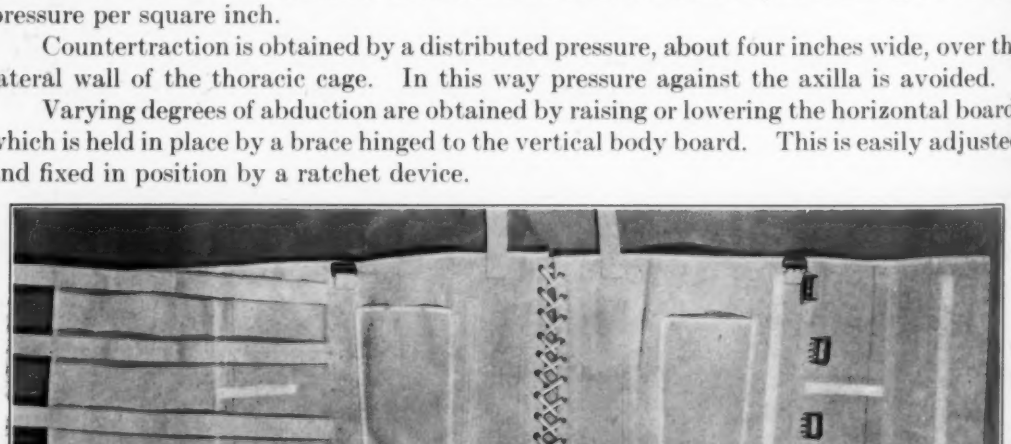

FIG. 3

After the proper amount of traction and abduction have been obtained, fixation is maintained by binding the arm and forearm to the carefully padded horizontal and arm boards. Multiple fractures involving the forearm, humerus, and ribs can be supported for transportation in this splint. Fractures immobilized in this manner lend themselves to careful observation, because they are accessible to palpation and roentgenographic examination, and yet are sufficiently fixed.

The splint weighs three and three-eighths pounds, and, when folded, measures six by four by twenty inches (Fig. 5). Its construction involves a form-fitting canvas belt and a wooden supporting structure. The canvas belt (Fig. 3) encircles the thoracic cage and is adjustable to a man of any size. It is overlapped in front and has a lacing in the back. Wrinkling is prevented by vertical stays. It is secured about the chest by four straps and buckles, and is suspended by two crossed shoulder straps. It has a pocket on each lateral side into which the splint can be inserted.

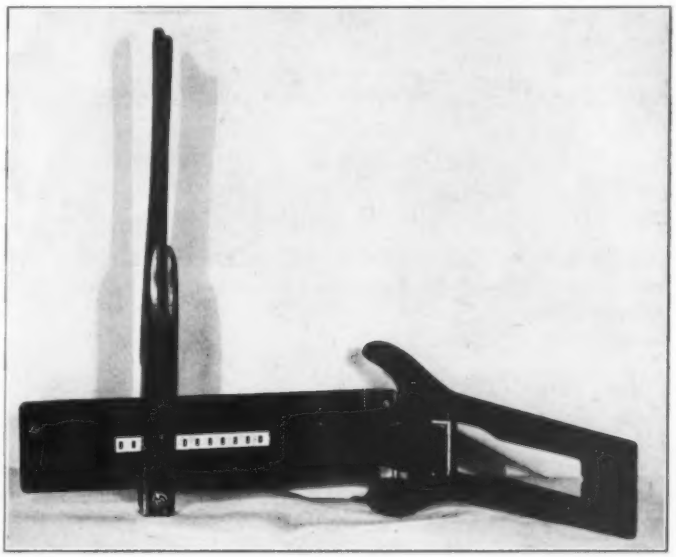

FIG. 4

The wooden part of the splint is made of resinated plywood. This wood possesses a powerful tensile strength, and is very light in weight. This supporting structure consists of three boards: a vertical board (Fig. 1-A), a horizontal board (Fig. 1-B) and a forearm board (Fig. 1-C).

FIG. 5

The vertical, fixed, body board is fifteen inches long. A crutch is carved out of its upper portion, and a brace is cut out of its central portion. This board fits into the pockets of the canvas belt, and stabilizes the supporting structure to the chest wall. It is seven inches wide at the crutch portion and rapidly tapers to a width of four inches. The brace measures one and one-half by seven inches, and is hinged at its upper portion so that it folds into the vertical board (Fig. 1-A).

The horizontal abduction board is hinged to the body board along its crutch surface. It measures fifteen by three and one-half inches, and contains an inserted ratchet bar (Fig. 1-B).

The arm board is cut to conform to the flexor surface of the forearm, and has a posterior extension around the ulnar side of the elbow (Fig. 1-C). This extension is thick enough to contain an adjustable slot which receives the abduction board and prevents rotation of the arm board upon it. A gap is cut out of the back of the slot, and a bolt with a thumb nut is placed through it. This allows the slot to be opened or closed enough to lock the arm board on the abduction board. Figures 2 and 4 show the wooden parts assembled.

It has been suggested that the splint be worn with the vertical board well toward the

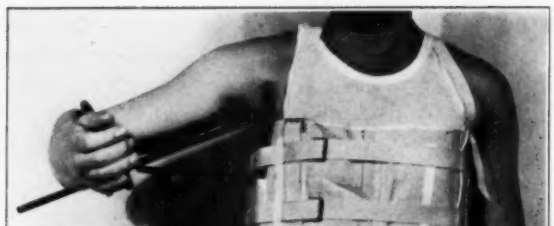

FIG. 6-A

FIG. 6-B

anterior axillary line, so that there will be no pull on the brachial plexus. Figures 6-A and 6-B show the splint in position.

The author wishes to thank Paul B. Magnuson, M.D., for his timely suggestions and help in presenting this splint, and to express his appreciation to Sergeant George Kendall and Vance Weskil for their time and effort in building the model.

DISCUSSION ON PAPERS OF DR. MURRAY, CAPT. MECH, LT. COL. BROWN, AND DR. MOORE

(*Continued from page 470*)

DR. H. W. ORR, LINCOLN, NEBRASKA: These papers, as well as the excellent Services we have been shown in our Military Hospitals, indicate to what heights, as operators, many of our orthopaedic surgeons have attained. However, may we not now begin to fear that, as technicians, some of them are becoming too much like some of the general surgeons we used to criticize, and are losing the orthopaedic point of view.

We find that some patients are being operated upon without preliminary correction of deformity. We find that they are being operated upon without correction of deformity at the time of operation. We find skin grafts being done on limbs that are useless at the time of operation, and are not reconstructed for best function afterward. It is impossible for many of us to comply with the requirements of Dr. Murray, as to local chemistry at the point of fracture, but we can see to it that the patient's chances are as good as possible to resist infection, and to initiate repair. We may still comply with those conditions as we understand them. It is also more likely that those patients will take care of themselves as far as the local physiology is concerned, if they are not too full of sulfanilamide, or any other toxic substances. What I want to demand under the circumstances is that, before we undertake these procedures, we adopt means to protect and stimulate the tissues, and that we shall maintain these limbs after operation in correct position, not only until the wound has healed, but until the disability has been reduced to a minimum and the anatomical and functional results are at their maximum.

LIEUTENANT COLONEL J. BARRETT BROWN, PHOENIXVILLE, PENNSYLVANIA (CLOSING): Bone grafts in the jaw will often work as Dr. Phemister has said. We have always used the simplest possible fixation, and sometimes rely on catgut to hold the graft in place. Bridging across a non-union without loss of substance is perhaps simpler than putting in a graft to replace a full-thickness loss of several centimeters. In this instance, the graft may have to help hold the fragments in place, in fact, act as part of the splinting itself as soon as it is in place, and, here, firm wiring to the fragments may be necessary, even though the wires may have to be removed later. This direct fixation and utilization of the graft for fixation of the fragments may avoid cumbersome intra-oral or extra-oral splinting.

DR. JOHN ROYAL MOORE, PHILADELPHIA, PENNSYLVANIA (CLOSING): The free graft advised by Dr. Phemister is excellent for partial defects, but is not satisfactory for massive defects. It is my impression that Dr. Phemister's conclusions are similar to my own.

A METHOD OF IMMOBILIZATION OF ACUTE ACROMIO-CLAVICULAR SEPARATION

BY MAJOR N. J. GIANNESTRAS

Medical Corps, Army of the United States

The treatment of an acute acromioclavicular separation by non-surgical means has long been a problem. Presented herein is a type of strap brace which has been found to work very satisfactorily in reducing a fresh separation of this joint, and in maintaining the reduction.

As shown in Figure 1-A, there are two pieces of webbing strap one inch in width; Strap *A*, forty inches long, and Strap *B*, forty-six inches long, are sewed together on a piece of piano felt, six inches square and one-quarter of an inch thick. The felt is used as a pressure pad at the point at which the straps cross the outer third of the clavicle. Strap *C*, which is seventeen inches long and has two loops, each two and a half inches in circumference, is applied just above the elbow to prevent any undue displacement of Strap *A*, which is applied around the forearm four inches distal to the olecranon process. The first loop in Strap *C* is one and a half inches from the edge of the buckle, and the second is five inches distant. Figure 1-B demonstrates in better detail the manner in which Strap *A* and Strap *B* are crossed and subsequently sewed together on the felt pad.

The action of the brace is such that it counteracts both the downward pull from the weight of the upper extremity and the upward pull of the sternomastoid muscle, thus overcoming and correcting the separation (Fig. 2).

The brace is applied as follows: Strap *C* is passed around the arm just above the elbow, and is buckled snugly with both loops pointing toward the trunk. The remainder of the brace is then placed over the outer third of the clavicle, with the short ends of the straps over the anterior surface of the shoulder when the apparatus is used on the right side,

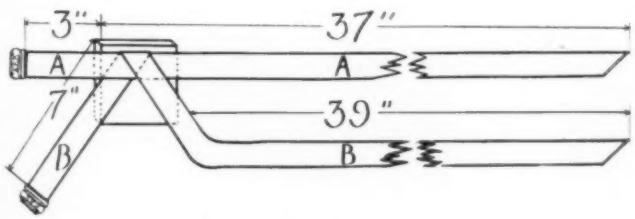

FIG. 1-A

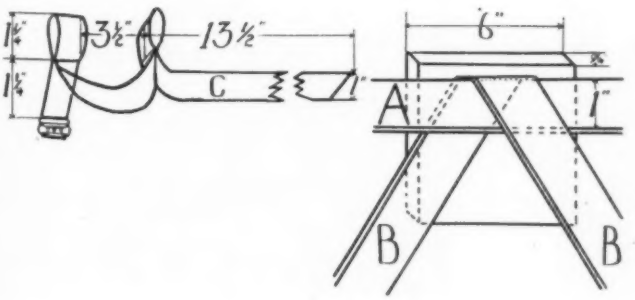

FIG. 1-B

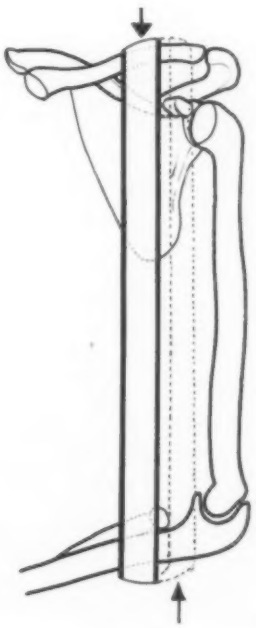

FIG. 2

Figs. 1-A and 1-B: Diagrams showing construction of brace.
Fig. 2: Showing mechanism of immobilization.

and over the posterior surface of the shoulder when used on the left side. This detail should be kept in mind, because, if it is not, the brace will be neither effective nor comfortable. As will be observed in Figure 3-A, the direction of the buckle end of Strap *A* is toward the elbow joint and that of Strap *B* is toward the opposite axilla.

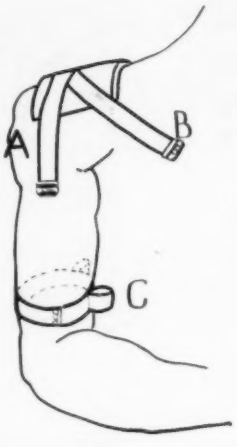

FIG. 3-A

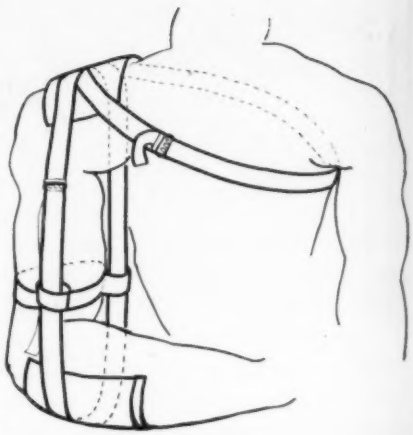

FIG. 3-B

Diagrams showing the apparatus applied.

After Strap *B* has been brought around the back and under the opposite axilla, it is passed through its corresponding buckle and tightened sufficiently to maintain the position of the pressure pad over the outer third of the clavicle. The long end of Strap *A* is passed through the posterior loop of Strap *C*, is brought around the forearm four inches distal to the olecranon process and over a piece of soft felt, and, with the elbow in 85 degrees of flexion, is passed through the anterior loop of Strap *C* and then through the buckle. Before the strap is tightened, the position of the pressure pad is checked again to make certain that it is over the outer third of the clavicle; the strap is then tightened until sufficient pressure has been exerted to reduce the separation. Figure 3-B demonstrates the brace completely assembled. It is important that Strap *A* be placed around the forearm exactly as directed—four inches distal to the olecranon process—because, if it is applied too near the elbow or too near the wrist, its function will be impaired. Figures 4-A and 4-B show anterior and posterior views of the brace as applied on a patient.

Figures 5-A and 6-A show two acromioclavicular separations taken in the standing

FIG. 4-A

FIG. 4-B

Photographs showing the apparatus applied.
(In preparing these illustrations, the negatives were reversed. The right arm should be shown.)

FIG. 5-A

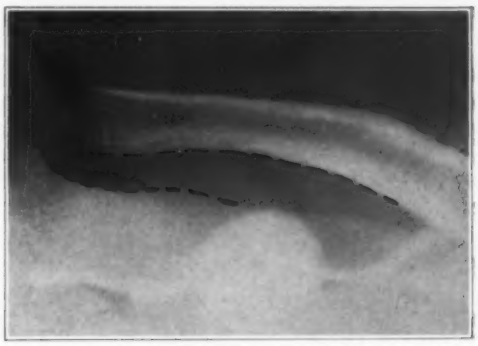

FIG. 6-A

Roentgenograms showing two cases of separation before treatment.

FIG. 5-B

FIG. 6-B

Roentgenograms showing the result of treatment in the same two cases.

position within twenty-four hours after the injury. Figures 5-B and 6-B show the same two cases taken in the standing position after the brace has been applied.

Immobilization is maintained for a period of three weeks. At the end of this time repair of the conoid and trapezoid ligaments and of the acromioclavicular capsule is usually complete, and, therefore, no further immobilization is required.

The question may be asked as to whether or not the brace should be removed when the individual goes to bed. The answer is, "No". One may question the effect of the brace during sleep, for after all, there is no restraining strap to prevent the individual from abducting his arm while asleep and thus releasing the pressure of the pad on the clavicle. This does and will occur, but in the recumbent position, the separation is spontaneously reduced, and, therefore, no pressure is required to maintain reduction.

This method has been found quite successful, and is presented at this time in the hope that at least some easy solution to the conservative method of treatment of this entity has been effected.

AN IMPROVED ABDUCTION SPLINT FOR THE UPPER EXTREMITY

BY HENRY H. JORDAN, M.D., NEW YORK, N. Y.

Many diseases and injuries of the upper extremity present definite indications for temporary fixation of the arm on an abduction splint.

The splint illustrated in Figures 1-A and 1-B fulfills all the requirements for fixation of the arm in abduction of 90 degrees, holding the humerus 25 to 40 degrees anterior to the frontal plane of the body.

The abduction-aeroplane splint prevents development of a contracture at the shoulder joint and relieves impairment of circulation in the arm (Figs. 2-A and 2-B).

The classic type of abduction-aeroplane splint has certain disadvantages which are chiefly responsible for the fact that this appliance is not well liked; and, consequently, has not found the general use which it undoubtedly deserves.

A new brace, recently developed, eliminates most of the disadvantages of the aeroplane splint. The new appliance has an even wider use, although it does not permit of the

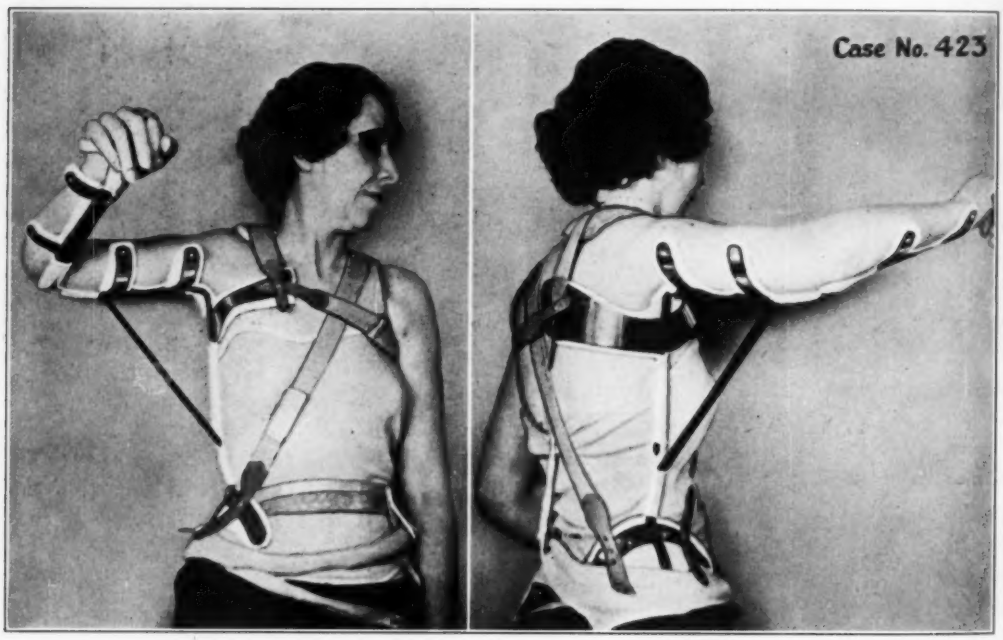

FIG. 1-A

FIG. 1-B

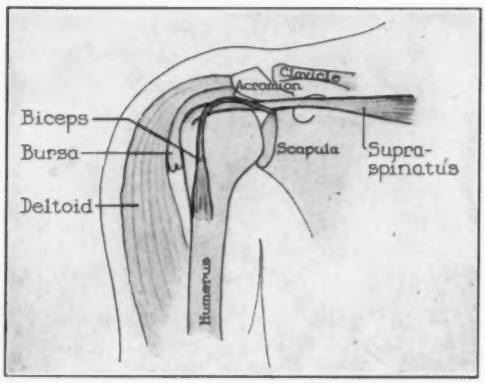

FIG. 2-A

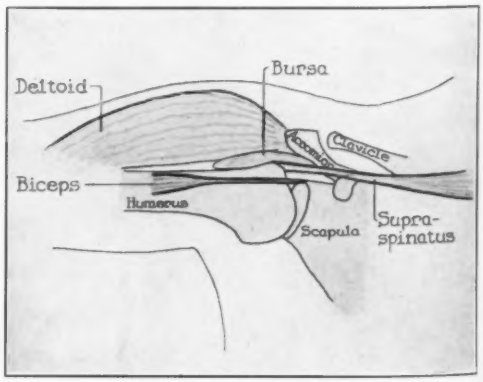

FIG. 2-B

FIG. 3-A

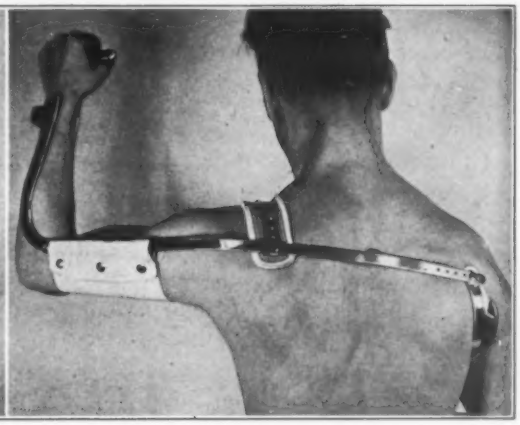

FIG. 3-B

degree of immobilization and fixation required for the treatment of certain fractures of the arm.

The abduction splint for the upper extremity, shown in Figures 3-A, 3-B, and 3-C, efficiently introduces the three-point system of forces required for all orthopaedic appliances. The weight of the normal upper extremity is used to balance the injured arm against the forces of gravity and contracture. The new appliance eliminates the four or five straps required to maintain correct position of the old aeroplane splint. It avoids pressure on the lateral chest wall, and on the iliac crest of the affected side.

FIG. 3-C

The new splint is much lighter and less bulky. It therefore requires less space for storage and shipping.

This abduction splint is easy to manufacture, and is suitable for mass production. Adequate "extensions" make it unnecessary to build the splint to individual measurements; only one size for the right and left upper extremity need be kept in stock. The new splint is readily adjusted, and is fitted, by means of screw driver and bending irons, to the adult patient of average size.

A SPLINT FOR RADIAL (MUSCULOSPIRAL) NERVE PALSY

BY MAJOR F. BRIAN THOMAS, R.A.M.C., SWANSEA, WALES

In wrist drop due to radial nerve palsy, the maintenance of full mobility in the fingers is of prime importance. Too often, after a wound or injury which paralyzes the radial nerve, active closure of the fist is lost for many weeks, or even months, by overzealous splinting in the traditional cock-up position. Complete absence of splinting for such cases is probably preferable to overfixation. The risk of stiffness developing in the fingers and thumb outweighs the harm done by stretching paralyzed muscles.

There are in common use three methods of splinting the dropped wrist:

1. *Long anterior cock-up splint.* This extends to the finger tips and is liable to produce stiffness, particularly of the metacarpophalangeal joints, even if removed frequently for physiotherapy. While being worn, it renders the hand completely useless functionally.

2. *Short anterior cock-up splint,* extending to the proximal interphalangeal joints. This is an improvement on the long cock-up splint, but there is still a likelihood of the metacarpophalangeal joints freezing in the extended position.

3. *Radial glove.* This apparatus robs the fingers of most of their tactile sense, and is apt to produce hyperextension at the terminal interphalangeal joints. It is not necessary to provide mechanical extension for the interphalangeal joints, which can be actively extended by the interossei and lumbricales.

With or without any of these devices, the patient with a radial nerve palsy is unable to use his hand to any appreciable extent. Full active use of the hand and fingers is the ideal to be aimed at for the preservation of movements and maintenance of function for a period of treatment, which may extend over many months. The splint described provides fixed dorsiflexion at the wrist with elastic extension for the thumb and for the metacarpophalangeal joints of the fingers, and the wearer is able to use the hand as efficiently as can the patient with a fractured wrist in plaster. There is no interference with the tactile sense of the fingers, which are completely uncovered; there is little interference in the case of the thumb, the terminal segment of which is supported in a thin leather sling. The fixation of the wrist does not produce stiffness of this joint, provided that it is not fixed in hyperextension, and provided that full mobility of the digits is maintained.

The splint in its simpler form (Fig 1) consists of a plaster cast (*A*) to which the devices for extending the fingers and thumb (*B* and *C*) are attached. The diagram and photographs show the construction and application of the splint, but a few important points must be emphasized.

The plaster cast is applied with the wrist in slight dorsiflexion. The lower end of the ulna is padded to prevent uncomfortable pressure at this point. Full flexion at the knuckle joints must be possible, and the metacarpal segment of the thumb must be left completely exposed. The cast is allowed to harden before the devices—the first, for extending the fingers and the second, for extending the thumb—are attached to it, each with a few turns of plaster bandage.

The wooden rod which extends the fingers lies transversely across the volar aspect of the proximal interphalangeal joints. When the fist is closed, this wooden rod does not travel in a straight path, but describes an arc of 90 degrees.

The curved, spring-steel wire passes dorsally between the third and fourth fingers, to be attached to the back of the cast. When the fingers are closed, the curve of the wire must be sufficient to keep it clear of the interdigital web. There is a subtlety in the action of this spring, which may not at first be obvious, but is important. The spring automatically changes the direction of its pull, when the fingers move from the extended to the

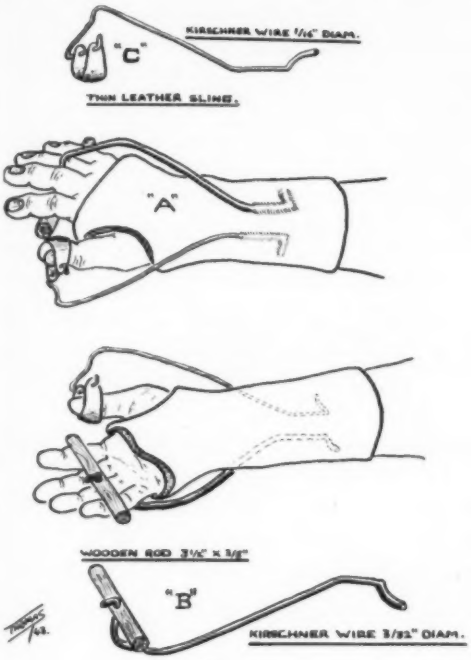

FIG. 1

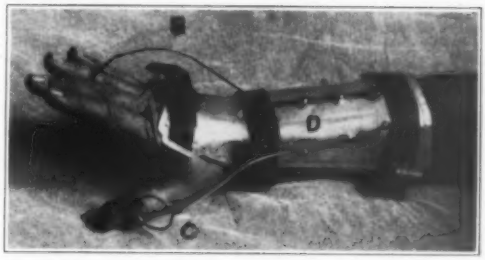

FIG. 2–A

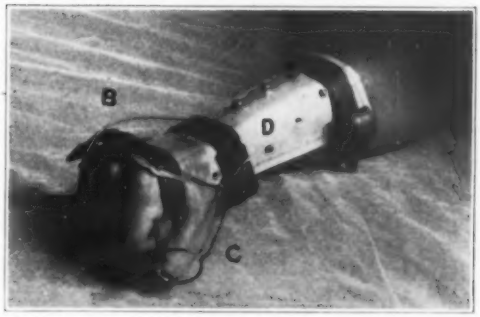

FIG. 2–B

FIG. 2–C

flexed position. Its action is that of two springs acting at right angles to each other. Thus, with the fingers extended, the pull is at right angles to the axis of the metacarpals; with the fingers flexed, the pull is in the long axis of the metacarpals. The pulp of the thumb rests in the leather sling, and the spring wire carrying this should produce full extension at all the joints of the thumb, and be sufficiently curved to allow full adduction of the thumb across the palm.

The plaster version of this splint as described above works efficiently, but has obvious drawbacks. The plaster becomes soiled and broken after a time, and requires renewal. It cannot be removed for washing, or for moving the wrist, should this be considered necessary. On the other hand, a great number of radial lesions have coexisting fractures or other injuries requiring plaster, and in these cases, the wires extending the fingers and thumb are used as accessories to the cast. They may be fitted to casts extending to below the elbow and above it, and to thoracobrachial plaster casts.

The metal version of the splint, shown in the photographs (Figs. 2–A, 2–B, 2–C, and 3) and in the drawing (Fig. 4), has many advantages. It is light in weight, easily detachable, can be used for the right or left hand, and stands up to prolonged use.

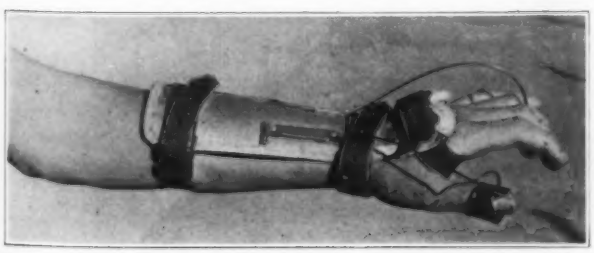

FIG. 3

The body (*D*), which is padded on its under side, is made from two pieces of thin-gauge sheet metal, riveted together. It is fitted to the dorsum of the hand and forearm by

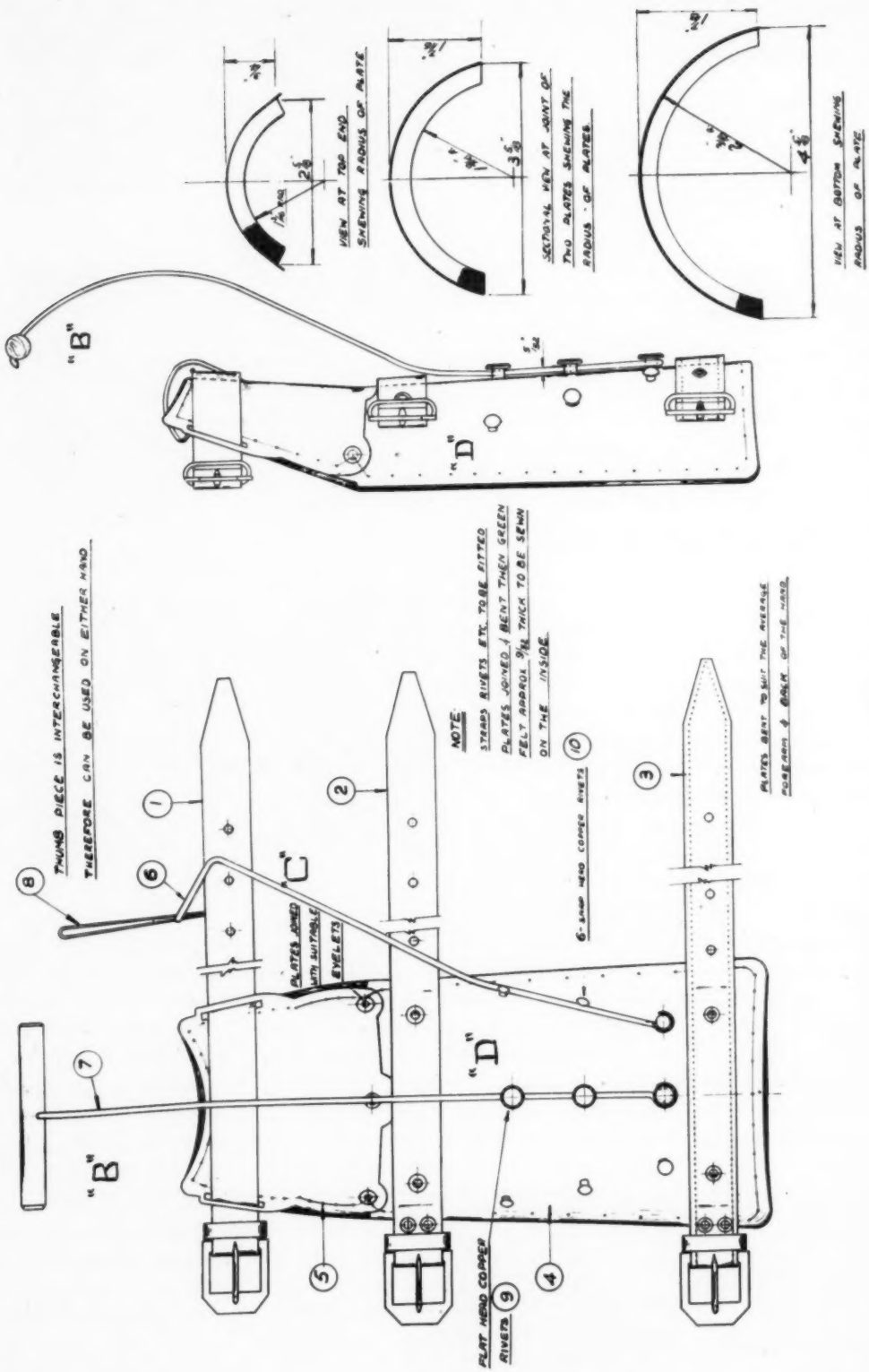
VIEW AT TOP END SHEWING RADIUS OF PLATE
SECTIONAL VIEW AT JOINT OF TWO PLATES SHEWING THE RADIUS OF PLATES.
VIEW AT BOTTOM SHEWING RADIUS OF PLATE
"B"
"D"
THUMB PIECE IS INTERCHANGEABLE
THEREFORE CAN BE USED ON EITHER HAND
NOTE
STAYS RIVETS ETC. TO BE FITTED
PLATES JOINED & BENT THEN GREEN
FELT ABOUT 3/16" THICK TO BE SEWN
ON THE INSIDE
6" SNAP HEAD COPPER RIVETS
PLATES BENT TO SUIT THE AVERAGE
FOREARM & BACK OF THE HAND
PLATES JOINED WITH SUITABLE EYELETS
"C"
"B"
"D"
FLAT HEAD COPPER RIVETS
1
2
3
4
5
6
7
8
9
10

FIG. 4

three leather straps, and the thinness of the metal enables it to be molded to conform to differing sizes of limbs. The strap running around the palm is buckled on the back of the splint to avoid interference with the grip. The thumb wire can be attached to either side of the body of the splint, making it interchangeable for right and left hands. This wire is adjusted for varying sizes of hands by bending the terminal loop (which carries the leather sling) proximally or distally. The finger-extending wire must also be adjusted by bending, so that the wooden rod lies in the correct position.

In conclusion, a few of the uses to which this splint has been put may be mentioned:

1. For uncomplicated radial and dorsal interosseous nerve palsies.
2. After nerve suture, while recovery is being awaited.
3. In conjunction with the "U" plaster and collar-and-cuff sling, for fracture of the humerus complicated by wrist drop.
4. Following tendon transplantation. After an initial three to four weeks' complete fixation on a long anterior cock-up plaster, the splint is fitted, and retained until full flexion is regained at the metacarpophalangeal joints. It permits a gradual return to full function, and diminishes the risk of straining the tendon anastomoses in the early stages.
5. In certain injuries of the extensor tendon where suture is precluded by recent sepsis.

My thanks are due to Brigadier Philip Wiles, Consultant Surgeon (Orthopaedic) M.E.F., for his encouragement and advice; to Colonel R. Lucas, O.B.E., M.C., for permission to publish this article; and to Captain King and the R.E.M.E., Radiological and Surgical Workshops, M.E.F. who made the splints and produced the machine drawings.

WILLIAM BEALL CARRELL

1883–1944

Dr. William B. Carrell died in Dallas, Texas, on February 26. Although ill health restricted his work in recent years, he made an outstanding contribution to his profession.

Born in Lawrence, Tennessee, on December 21, 1883, he moved to Texas when a boy. He received his degree of Bachelor of Science at Southwestern University in 1905, and his degree in Medicine from the Medical School of the same University in 1908.

Dr. Carrell was always interested in children, and was one of the pioneers in his State in the work for crippled children. Many years ago he was instrumental in the passage of legislation providing care for indigent children who were victims of infantile paralysis, and he was one of the organizers of the Texas Society for Crippled Children. In recent years he became keenly interested in the work of the National Foundation for Infantile Paralysis and devoted much time to the research sponsored by the Foundation. He gave valuable aid in fighting the epidemic of infantile paralysis in Texas in the summer of 1943.

He was Professor of Orthopaedic Surgery at Baylor School of Medicine, Orthopaedic Surgeon at the Baylor, Methodist, and Parkland City Hospitals, and Chief Surgeon of the Texas Scottish Rite Hospital for Crippled Children.

In World War I, he served as Captain and later as Major in the Medical Corps of the United States Army.

He was a member of the American Orthopaedic Association, the Central States Orthopaedic Society, the Southern Medical Association, a Fellow of the American Academy of Orthopaedic Surgeons and of the American College of Surgeons, and held membership in many other medical organizations. He had served as President of the Texas Orthopaedic Association and of the Clinical Orthopaedic Society.

His interests in his community were varied. In 1925 he received the Linz award for outstanding service as a Dallas citizen. He was a thirty-third-degree Mason, a member of the Rotary Club and of many local clubs.

In 1905 he was married to Beulah Stewart, of Dallas, who survives him, as do two sons and a daughter. His older son, Dr. Brandon Carrell, was associated with him in the Carrell-Girard Clinic.

Dr. Carrell contributed many articles to the medical literature, especially in the field of treatment of crippled children, the work to which so much of his life was devoted.

A man of great kindness, of high ideals, and of superior ability, he was greatly beloved by a host of friends and associates. In the death of Dr. Carrell the Association has lost a valuable member.

News Notes

The Second Wartime Public Health Conference and Seventy-Third Annual Business Meeting of the **American Public Health Association** will be held in New York City on October 3, 4, and 5. The program will be devoted to wartime emergency matters as they affect public health. Meetings of related organizations will be held on Monday, October 2. Headquarters will be at the Hotel Pennsylvania.

The **Biological Photographic Association** will hold its Fourteenth Annual Meeting on September 7, 8, and 9 in Binghamton, New York. This meeting will be of special interest not only to scientific photographers but to scientific workers who use biological and medical photography. Information about the meeting may be obtained from The Secretary of the Biological Photographic Association, University Office, Magee Hospital, Pittsburgh, Pennsylvania.

The Ninth Annual Assembly of the **International College of Surgeons** will be held on October 3, 4, and 5 at the Benjamin Franklin Hotel in Philadelphia. This Assembly is sponsored by the United States Chapter of the College, of which Dr. Thomas A. Shallow of Philadelphia is President. Dr. Rudolph Jaeger of Jefferson Medical College is General Chairman of the committee on arrangements. The program will be devoted to wartime rehabilitation and civilian surgery.

At the meeting of the **Sociedad Cubana de Ortopedia y Traumatología,** held in May, the following officers were elected for the year 1944–1945:

President: Dr. Alberto Inclán.
Vice-President: Dr. Rafael Peñalver.
Secretary: Dr. Luis Iglesias de la Torre.
Vice-Secretary: Dr. Harry Romney.
Treasurer: Dr. Pedro Sánchez Toledo.
Vice-Treasurer: Dr. José I. Tarafa.

The **Atlas of Orthopedic Pathology,** prepared at the Army Medical Museum from material in The Registry of Orthopedic Pathology, was issued in the fall of 1943. This was sponsored by The American Academy of Orthopaedic Surgeons and The American Board of Orthopaedic Surgery. Copies have been sent to members of the Academy. A few copies are now available for sale, and may be obtained from the Secretary of the Committee on Registry of Orthopaedic Pathology, Dr. Paul C. Colonna, 3400 Spruce Street, Philadelphia, Pennsylvania. The price is $5.00 per copy, and remittance should be sent with the request.

The **Research Institute Foundation, Inc.,** was incorporated in November 1943, as a non-profit, scientific research organization, by the Association of Limb Manufacturers of America, Inc. The Board of Governors represents The American Academy of Orthopaedic Surgeons, The American Orthopaedic Association, the Association of Limb Manufacturers of America, Inc., the Office of the Surgeon General of the United States Army, the Bureau of Medicine and Surgery of the United States Navy, United States Veterans' Administration, Disabled American Veterans, and the American Federation of the Physically Handicapped. A scientific laboratory is to be established in Detroit, Michigan. Any suggestions for research and development may be presented to the Foundation, and any developments or devices released by the Foundation will be free to all so long as they are used ethically for the public good.

The need for a scientific organization of this kind has long been felt. The emergencies of War have brought the organization into being. Any truly scientific effort in the development of artificial limbs and of orthopaedic apparatus must result from the combined thinking of those who make the appliances and those who prescribe their use.

The third edition of the **Directory of Medical Specialists,** listing names and biographical data of all men certified by the fifteen American Boards, is to be published early in 1945. Collection of biographical data of the Diplomates certified since the 1942 edition, and revision of the older listings in that volume are now going forward rapidly. Diplomates are requested to make prompt return of notices regarding their biographies as soon as possible after receiving the proper forms from the publication office soon to be mailed to them.

GUY A. CALDWELL, M.D., *Secretary.*
American Board of Orthopaedic Surgery, Inc.

INTERNATIONAL CONFERENCE ON AMPUTATIONS AND ARTIFICIAL LIMBS

An International Conference on Amputations and Artificial Limbs was held in Ottawa, Ontario, and Toronto, Ontario, February 15–17, 1944. It was organized by the Section on Orthopaedics of the National Research Council of Canada, under the Chairmanship of Colonel R. I. Harris, with the cooperation of the Department of Pensions and National Health.

Canadian surgeons in the Department of National Defence had been anxious to meet the surgeons from the British Army and Ministry of Pensions, in order to lay before them the merits of the Canadian practice, particularly in regard to the Syme and the Stokes-Gritti amputations. British opinion seemed to oppose such stumps. Since Canadian soldiers are to be brigaded with the British Army, they are quite likely to be treated by British surgeons, and the surgical consultants in the Canadian Services are anxious that they be provided with the type of amputation stump which has proved practical in Canada. It was felt, moreover, that technical improvements in prostheses had been developed in the United States, England, and Canada, which might profitably be shared by all.

Accordingly, when the Panel on Amputations of the Subcommittee on Orthopaedic Surgery of the National Research Council in Washington expressed a desire to see the Canadian practice in amputations, the time seemed opportune to arrange a conference.

Invitations were extended to, and accepted by, the following organizations:—the United States Army, who sent the Surgeon General, Maj. Gen. Norman Kirk and a group of consultants; the United States Navy, represented by Rear Admiral Laning, Capt. Kessler and Capt. Barr; the Air Surgeon's Office; the United States Public Health Service; the National Research Council; the Veteran's Bureau; and the Association of Artificial Limb Manufacturers; the British Army, represented by Col. F. S. Gillespie; the Ministry of Pensions, represented by Dr. R. W. Langdale Kelham and Mr. George Perkins. The Union of Socialist Soviet Republics sent Prof. Vladimir Lebedenko; Australia was represented by Squadron Leader R. V. Pridmore. Canadian delegates included the Medical Director General of the Navy, Surg. Capt. A. Macallum, and naval surgeons; the Director General of the Medical Service of the Army, Maj. Gen. C. B. Chisholm; the Surgical Consultant in Britain, Col. J. A. Macfarlane; the surgical consultants in Canada; surgeons from the Army, Air Force, Department of Pensions and National Health, and the National Research Council. Of the ninety delegates registered, one third came from outside Canada.

A great many subjects were discussed, and demonstrations were provided by the participants. The delegates spent two hours looking over the artificial limb factory at the Christie Street Hospital, Toronto. A summary of the most important features of the conference follows:—

The experience of the Allied surgeons in various theaters of war, including the Russian, led to the expression of a common policy in respect to amputations in the field,—that they should be done to save life and control infection, in such a manner as to preserve the greatest possible length of extremity, by the modified guillotine or open-flap method, and with a view to later reamputation for prosthetic fitting.

Mr. George Perkins extolled the British procedure of having a limb-fitting surgeon to advise the amputating surgeon as to the nature and site of the definitive amputation, and, later, to supervise the fitting of the prosthesis and instruction in its use. He demonstrated the Roehampton methods of exercise of stump muscles.

Conflicting opinions were offered regarding the preparation of the amputation stump for the prosthesis. The British surgeons advocate shrinkage entirely by bandaging; and Dr. Kelham demonstrated their method of application of the bandage. The Canadians and Americans bandage also, but believe that a temporary artificial limb is essential to complete the shrinkage. The Canadians, who use a peg leg, were greatly impressed by the provisional fiber limb used in the American Army.

Dr. G. M. Dale, of the Department of Pensions and National Health, Canada, had assembled at the Christie Street Hospital, fifty-five amputees to demonstrate the Canadian practice. The British and American delegates were convinced of the merits of the Stokes-Gritti and Syme amputations; it was conceded that climatic conditions in Britain may be responsible for circulatory disturbances in end-bearing stumps in that country.

Capt. H. H. Kessler, U.S.N., provided an excellent demonstration, by picture and patient, of the usefulness of the cineplastic amputation.

Demonstrations of favorite prostheses were provided by the American, British, and Canadian delegates. Dr. Kelham showed many pictures of amputees at Roehampton, using their appliances. Agreements were reached on a common policy with respect to such subjects as: treatment of the nerve; ideal length of leg, thigh, and arm stumps; postoperative treatment of guillotine amputation; rehabilitation of the amputee, *et cetera*.

The British and American delegates had great praise for Col. Harris and his committee, for providing an outstanding program for which all had worked hard and from which all profited greatly. It was suggested that another conference be held within eighteen months, to consider further progress in the field of amputations.

G. H. ETTINGER, *Hon. Sec., Subcommittee on Surgery,*
National Research Council, Ottawa.

THE AMERICAN ORTHOPAEDIC ASSOCIATION

The Fifty-Eighth Annual Session of The American Orthopaedic Association, under the Presidency of Dr. A. Bruce Gill, was held at The Homestead, Hot Springs, Virginia, on June 1, 2, and 3, 1944.

The following papers were presented:

Thursday, June 1

Morning Session

Healing Time in Fractures of the Shafts of the Tibia and the Femur.
Dr. Robert V. Funsten, Charlottesville, Virginia.
Dr. Robert W. Lee, Charlottesville, Virginia. (By invitation.)
Discussion: Dr. H. Earle Conwell, Birmingham, Alabama.
Captain C. M. Shaar, M.C., U.S.N. (By invitation.)

Cervico-Axial Osteotomy. A Preliminary Report.
Dr. Guy W. Leadbetter, Washington, D. C.
Discussion: Dr. J. Albert Key, St. Louis, Missouri.
Dr. Charles W. Peabody, Detroit, Michigan.
Dr. Walter P. Blount, Milwaukee, Wisconsin.
Dr. Rudolph S. Reich, Cleveland, Ohio.
Dr. Ralph K. Ghormley, Rochester, Minnesota.
Dr. Paul B. Magnuson, Chicago, Illinois.

Arthrodesis of the Ankle Joint for Old Painful Fractures.
Dr. Halford Hallock, New York, N. Y.
Discussion: Dr. Harold R. Conn, Akron, Ohio.
Dr. J. Albert Key, St. Louis, Missouri.
Dr. William E. Gallie, Toronto, Ontario, Canada.

Carpal Scaphoid Fractures.
Dr. D. M. Meekison, Vancouver, British Columbia, Canada.
Discussion: Dr. R. I. Harris, Toronto, Ontario, Canada.
Major Joseph E. Milgrim, M.C.

Posterior Approach to the Femur.
Dr. David M. Bosworth, New York, N. Y.
Discussion: Dr. James S. Speed, Memphis, Tennessee.
Dr. J. Albert Key, St. Louis, Missouri.

Subtibial Collateral Ligament Bursitis.
Dr. Allen F. Voshell, Baltimore, Maryland.
Dr. Otto C. Brantigan, Baltimore, Maryland. (By invitation.)
Discussion: Dr. Ralph K. Ghormley, Rochester, Minnesota.
Dr. Robert B. Osgood, Boston, Massachusetts.

Afternoon Session

Epidemiology of Poliomyelitis.
Dr. Robert Ward, New Haven, Connecticut. (By invitation.)

Pathology and Pathogenesis of Poliomyelitis.
Dr. A. B. Sabin, Cincinnati, Ohio. (By invitation.)

The Use of Dihydro-Beta-Erythroidine in Acute Infantile Paralysis and Spastic Paralysis.
Dr. R. Plato Schwartz, Rochester, New York.

Results of Modern Methods of Treatment of Poliomyelitis.
Dr. Robert W. Johnson, Jr., Baltimore, Maryland.

Calcification (Periarticular) following Anterior Poliomyelitis in an Adult.
Dr. Joseph A. Freiberg, Cincinnati, Ohio.
(This paper was read by title.)

Abstract of Report of Committee Investigating Kenny Method of Treatment.
Dr. Ralph K. Ghormley, Rochester, Minnesota.
Discussion of the foregoing papers:
Dr. J. Albert Key, St. Louis, Missouri.
Dr. A. Bruce Gill, Philadelphia, Pennsylvania.

Surgical Approaches to the Knee Joint.
Dr. LeRoy C. Abbott, San Francisco, California.
Dr. Walter F. Carpenter, San Francisco, California. (By invitation.)
Discussion: Dr. John R. Moore, Philadelphia, Pennsylvania.

FRIDAY, JUNE 2

Morning Session

Bone Sarcoma following Radiation Therapy.
Dr. C. Howard Hatcher, Chicago, Illinois.
Treatment of Benign Giant-Cell Tumors by Excision and Bone-Grafting.
Dr. Henry W. Meyerding, Rochester, Minnesota.
Discussion of the two preceding papers:
Dr. Carl E. Badgley, Ann Arbor, Michigan.
Dr. N. S. Ransohoff, New York, N. Y.
Dr. Alberto Inclán, Havana, Cuba.
Dr. C. Leslie Mitchell, Detroit, Michigan.
Bone-Growth Retardation by a Wire Loop about the Epiphyseal Cartilage Plate.
Dr. Sylvan L. Haas, San Francisco, California.
Discussion: Dr. John R. Moore, Philadelphia, Pennsylvania.
Equalization of Leg Length with Comparison of the Results of Epiphysiodesis and Femoral Shortening.
Dr. Philip D. Wilson, New York, N. Y.
Lieutenant Colonel T. Campbell Thompson, M.C.
Discussion: Dr. J. Warren White, Greenville, South Carolina.
Discussion of the two preceding papers:
Dr. Dallas B. Phemister, Chicago, Illinois.
Herniation of the Nucleus Pulposus. A Study of One Hundred Cases Operated on at the New York Orthopaedic Hospital.
Dr. Alan DeForest Smith, New York, N. Y.
Dr. Edwin M. Deery, New York, N. Y. (By invitation.)
Dr. George L. Hagman, New York, N. Y. (By invitation.)
Discussion: Captain Joseph S. Barr, M.C., U.S.N.R.
Dr. J. Albert Key, St. Louis, Missouri.
Dr. Frank R. Ober, Boston, Massachusetts.
Osteotomy of the Spine.
Dr. M. N. Smith-Petersen, Boston, Massachusetts.
Discussion: Dr. George E. Bennett, Baltimore, Maryland.
Dr. H. R. McCarroll, St. Louis, Missouri.

Afternoon Session

President's Address.
Dr. A. Bruce Gill, Philadelphia, Pennsylvania.
The Basic Problems in Bone-Grafting for Ununited Compound Fractures.
Dr. Clay Ray Murray, New York, N. Y. (By invitation.)
Wound Healing in Compound Fractures and Repair of Bone Defects.
Captain Karl F. Mech, M.C. (By invitation.)
Surface Repair of Compound Injuries.
Lieutenant Colonel James Barrett Brown, M.C. (By invitation.)
Bridging of Bone Defects in Compound Wounds.
Dr. John R. Moore, Philadelphia, Pennsylvania.
Discussion of the four foregoing papers:
Dr. Paul B. Magnuson, Chicago, Illinois.
Dr. Dallas B. Phemister, Chicago, Illinois.
Dr. William E. Gallie, Toronto, Ontario, Canada.
Major General Norman T. Kirk, Washington, D. C.
Dr. J. Albert Key, St. Louis, Missouri.
Dr. H. Winnett Orr, Lincoln, Nebraska.

SATURDAY, JUNE 3

Morning Session

Management of Compound Fractures in a Field Surgical Unit.
Captain Bruce Tovee, M.C., Toronto, Ontario, Canada. (By invitation.)
Anatomical and Physiological Considerations in the Alignment and Fitting of Amputation Prostheses for the Lower Extremity.
Dr. Atha Thomas, Denver, Colorado.
Amputations.
Dr. R. I. Harris, Toronto, Ontario, Canada.

The Army Amputation Program.
Colonel Leonard T. Peterson, M.C., Washington, D. C. (By invitation.)
Amputations—Surgery and Plastic Repair.
Lieutenant Colonel T. Campbell Thompson, M.C.
Dr. Rufus H. Alldredge, New Orleans, Louisiana. (By invitation.)
Upper Extremity Amputations and Prostheses.
Colonel Francis M. McKeever, M.C.
Discussion—Summary.
Major General Norman T. Kirk, Washington, D. C.

An Executive Session was held at noon on Thursday, and the meeting closed with the final Executive Session, Saturday, June 3, at noon.

At an Informal Dinner, on Thursday evening, talks were given by members returned from foreign service. At the Association Banquet, held on Friday evening, June 2, to which guests were invited, the speakers were Major General Norman T. Kirk, Captain C. M. Shaar (for Vice Admiral Ross T. McIntire), and Brigadier General Rankin.

At the last Executive Session, the President for the ensuing year, Dr. J. Albert Key, St. Louis, Missouri, was presented.

The following officers, committeemen, and members were elected:

Officers

President-Elect: Dr. LeRoy C. Abbott, San Francisco, California.
Vice-President: Dr. William Turner, Montreal, Canada.
Secretary: Dr. Charles W. Peabody, Detroit, Michigan.
Treasurer: Dr. Frank D. Dickson, Kansas City, Missouri.

Committee members and representatives

Membership Committee: Dr. Arthur G. Davis, Erie, Pennsylvania.
Program Committee: Dr. John L. McDonald, Toronto, Ontario, Canada.
Research Committee: Dr. C. Howard Hatcher, Chicago, Illinois.

Representatives on the American Board of Orthopaedic Surgery:

Dr. G. E. Haggart, Boston, Massachusetts.
Dr. Allen F. Voshell, Baltimore, Maryland.

New active members

Dr. Harold B. Boyd, Memphis, Tennessee.
Dr. Joseph Buchman, New York, N. Y.
Dr. B. Franklin Buzby, Camden, New Jersey.
Dr. Louis G. Howard, Boston, Massachusetts.
Dr. Armin Klein, Boston, Massachusetts.
Dr. Leo S. Lucas, Portland, Oregon.
Dr. John Ratcliffe Naden, Vancouver, British Columbia, Canada.
Colonel Leonard T. Peterson, United States Army, Washington, D. C.
Dr. Ralph Soto-Hall, San Francisco, California.
Dr. Richmond Stephens, New York, N. Y.
Lieutenant Commander James W. Toumey, Boston, Massachusetts.

The meeting was probably one of the most interesting of the Association. The excellent program was arranged by the Committee of which Dr. Myron O. Henry was Chairman. As would be expected, the emphasis was on subjects and discussions related to war casualties and problems of reconstruction surgery.

Current Literature

VASCULAR RESPONSES IN THE EXTREMITIES OF MAN IN HEALTH AND DISEASE. David I. Abramson, M.D., F.A.C.P. Chicago, The University of Chicago Press, 1944. $5.00.

This volume, ninth in the series sponsored by The University of Chicago Committee on Publications in Biology and Medicine, is the scholarly record of a decade of clinical and experimental research into the problems of peripheral vascular disease.

The author, now a Captain in the United States Army Medical Corps, first reviews the normal anatomy, physiology, and nerve-control mechanisms of the blood vessels in the extremities, and outlines the methods, qualitative and quantitative, employed in studying the rate of peripheral blood flow. He attaches most importance and value to the venous occlusion plethysmograph, and describes in detail the equipment and technique necessary for its use.

Next he discusses the physiological responses of blood vessels in the extremities to position, heat, cold, humidity, food, menstruation, pregnancy, anoxia, effort and fatigue, and to a variety of pharmacological agents. Some of the latter material is drawn from his review, previously published by Lippincott, on the peripheral vascular action of various drugs.

The author summarizes the clinical application of his blood-flow studies to the problems of abnormal states and systemic diseases, and of peripheral vascular diseases, functional and organic. Finally, he evaluates the various methods of treatment employed,—mechanical procedures, vasodilator drugs, sympathectomy, external heat, and artificial-fever therapy.

The book, which is illustrated with fifty-nine admirable figures and well documented with a bibliography of over 1000 references to the literature, presents the latest authoritative data in this important field.

FUNCTIONAL DISORDERS OF THE FOOT. THEIR DIAGNOSIS AND TREATMENT. Frank D. Dickson, M.D., F.A.C.S., and Rex L. Diveley, A.B., M.D., F.A.C.S. Ed. 2. Philadelphia, J. B. Lippincott Company, 1944. $5.00.

A second edition of this book by Dr. Dickson and Dr. Diveley is fully justified, for it presents in succinct form the consensus concerning the subjects with which it deals.

The introductory chapters deal with the evolution of the human foot and its anatomy. They explain the effects that disturbance of that anatomy have on the physiology of an individual, whether the disturbance be from hereditary causes, trauma, or the strain of postural or other causes for throwing the statics of the body out of line.

The importance of a thorough physical appraisal of a patient suffering from functional foot troubles is properly emphasized.

The discussion of foot imbalance, both in childhood and adult life, strikes at the root of the whole matter, so far as treatment is concerned, for the treatment should be directed to the prevention and the management of the early stages of these troubles.

The authors lay emphasis on the importance of proper shoeing, and offer practical suggestions which, if followed, would unquestionably lessen the amount of these troubles that are brought to the attention of orthopaedic surgeons.

In cases where surgical interference is required, the measures advocated are sound and clearly described.

The new and timely features of this second edition are the chapters on the foot in military service and in industry.

One could not go wrong in following the recommendations in this text

TECHNIQUE IN TRAUMA. PLANNED TIMING IN THE TREATMENT OF WOUNDS INCLUDING BURNS. Fraser B. Gurd, M.D., C.M., and F. Douglas Ackman, M.D., C.M. Philadelphia, J. B. Lippincott Company, 1944. $2.00.

Material previously published in the *Annals of Surgery*, with certain additions, has been collected in a small, very attractive monograph, with excellent colored illustrations.

The "Montreal method" of treating burns is explained, and the results of a large series of cases are given. Great emphasis is laid on timing various procedures. The treatment given the first hour is morphine, serum or plasma, heat in a tent, water by mouth, oxygen, intravenous glucose saline, hemoglobin and hematrocrit determinations. In the first forty-eight hours, shock must be combatted. As soon as possible the wound is débrided without anaesthesia, and is washed with soap solution, followed by salt solution. A coarse mesh dressing, covered by several layers of gauze soaked in an emulsion of 5 per cent. sulfathiazole

oil in water, is then placed over the wound. Outside this is a pressure dressing of cotton waste, held in place with firm bandages.

Toxaemia is watched for from the second to the fifth days, infection from the fifth to the fourteenth days. Healing occurs from the second to the sixth week. Thick split grafts are applied as soon as possible, certainly by the fourteenth day.

INTRAVENOUS ANESTHESIA. R. Charles Adams, M.D., C.M., M.S. (Anes.). New York, Paul B. Hoeber, Inc., 1944. $12.00.

The many surgeons and anaesthesiologists, who have been wishing that someone would collect and evaluate the present-day knowledge regarding intravenous anaesthesia, have great cause for satisfaction in this book. It is a really comprehensive treatise on the subject. Approximately the first half of the volume consists of a thorough review of the literature concerning the development of the method and the pharmacology of the earlier agents used. This section is of particular value to anaesthesiologists and laboratory workers, since it makes so much material available for ready reference. The latter part of the book is devoted to the two agents most used for intravenous anaesthesia at present,—evipal soluble and pentothal sodium. In this connection, the author offers a review of the literature, correlating and discussing the material in the light of his extensive experience. Clinicians will appreciate the definite advice offered concerning indications, contra-indications, and technique for intravenous anaesthesia. The author's recommendations relative to its selection are conservative, and he advises caution in its application by those inexperienced in using it. The text is illustrated with photographs and drawings which do much to clarify descriptions of technique. The bibliography is exhaustive, and is arranged at the end of the chapters for easy reference. The last chapter deals with intravenous anaesthesia in military surgery.

MINOR SURGERY. Edited by Humphry Rolleston and Alan Moncrieff. New York, Philosophical Library, 1944. $5.00.

This book is a series of monographs by various British authors, and is intended for use by the general practitioner.

It is always difficult to draw the line between major and minor surgery. Tonsillectomy and incision of an ear drum are considered minor procedures, but the specialist in otolaryngology does not consider them such. Amputation of the cervix may be minor, as opposed to hysterectomy, but it is not rated as such by a trained gynecologist. It should be kept in mind when reading this book that, while the conditions described and the operative procedures carried out are lesser operations, they are no less important than certain major operations.

The various chapters cover minor wounds, sprains, the feet, the hands, the mouth, the nose and throat, the eye and ear, bursae and ganglia, benign tumors and cysts, the rectum, genito-urinary system, the non-operative treatment of hernias, varicose veins, gynecology, childhood conditions, and anaesthesia.

The book has a limited use for students and practitioners who wish to read a few lines on many subjects. The illustrations, which are few, are grouped on a few pages, and are not particularly helpful. They consist mostly of cuts of instruments. Printing restrictions have doubtless limited the use of further cuts.

TROPICAL NURSING. A HANDBOOK FOR NURSES AND OTHERS GOING ABROAD. A. L. Gregg, M.D., M.Ch. Ed. 2. New York, Philosophical Library, 1944. $3.00.

This is a very convenient and useful book for the nurse or the layman who is going to live in tropical climates. The most important tropical diseases are taken up with considerable detail, and a brief summary is given of the cause, prevention, symptoms, clinical course, treatment, and prognosis for each disease. In such diseases as malaria, in which the laboratory work is of primary importance in diagnosis, methods of making blood smears and staining technique are given.

Personal hygiene in the tropics is discussed in detail. The precise technique which may be carried out by the nurse for certain procedures—such as blood transfusion, intramuscular injection, intravenous injection, and bowel lavage—is included.

Many public-health procedures are given, which help in the prevention and control of these tropical diseases which are new to so many people.

The author, who is a member of the staff at the Hospital for Tropical Diseases in London, has written a valuable manual for meeting the public-health problems of the present day.

VIRUS DISEASES IN MAN, ANIMAL, AND PLANT. Gustav Seiffert. (Translation by Marion Lee Taylor, Ph.D.) New York, Philosophical Library, 1944. $5.00.

This book is a review of some of the work on virus diseases which has been done during the last decade. The virus diseases and similar infections which occur not only in man, but in birds, animals, and plants,

are considered. The history, investigative work, and pertinent methods are given in regard to each of some seventy conditions.

A general discussion is given of the history, nature, terminology, procedures used in working with viruses, and immunity to virus diseases.

The book is of value to a person who is well acquainted with this field, because of many details of technique which are given and the references to foreign literature. To a person who is unfamiliar with this special field, the methods are not presented clearly enough to follow. While the author is apparently well equipped to write on this subject, the book has lost some of its value in the translation which does not always use commonly accepted scientific terms.

THE AMERICAN ILLUSTRATED MEDICAL DICTIONARY. W. A. Newman Dorland, A.M., M.D., F.A.C.S., with the collaboration of E. C. L. Miller, M.D. Ed. 20. Philadelphia, W. B. Saunders Company, 1944. Plain $7.00, thumb indexed $7.50.

To those working in all phases of the medical sciences an up-to-date reliable medical dictionary is a necessity. The new edition of Dorland's will be welcomed by all such workers, for it includes many of the new terms which have found their way into the medical literature in the last three years. The greater emphasis on war medicine and surgery, the more general interest in tropical and parasitic diseases, the advances in the fields of biochemistry, chemotherapy, mycology, and vitamin research, all are reflected in this important new edition.

Individuals, as well as hospitals, libraries, and even medical journals, find in each new edition of this excellent work an expanding field of knowledge and an ever-increasing storehouse of facts which help to make their work more accurate.

The editors and publishers are to be congratulated on the twentieth edition of this valuable reference book.

SMALL COMMUNITY HOSPITALS. Henry J. Southmayd and Geddes Smith. New York, The Commonwealth Fund, 1944. $2.00.

This compact little book, issued by the Commonwealth Fund, is the result of the experience of its Division of Rural Hospitals in studying the medical problems of many communities. The aid of the Fund in the building of thirteen small hospitals in various rural districts is one step in the solution of these problems.

Emphasis is placed on high standards of service—medical, nursing, and administrative—in these small hospitals, and the sense of community responsibility for adequate hospital care within the reach of all. The recognition of the difficulties to be found in districts of small populations spread over comparatively large areas, and the very practical methods outlined for meeting these conditions should be of interest to many who are studying the question of providing suitable medical care for the citizens of the rural communities of our country.

EOSINOPHILIC GRANULOMA WITH REPORT OF ONE CASE INVOLVING FIRST THE MANDIBLE, LATER OTHER BONES, AND BEING ACCOMPANIED BY DIABETES INSIPIDUS. Kurt H. Thoma. *American Journal of Orthodontics and Oral Surgery (Oral Surgery Section)*, XXIX, 641, 1943.

A case of eosinophilic granuloma is reported, which affected the mandible extensively in the incisor and premolar region on the right, and in the premolar and molar areas on the left. In addition, there was a small circular defect in the posterior portion of the right parietal bone 4.5 centimeters from the middle, and a smaller one near the sagittal suture. The skeleton was elsewhere normal, except for one minute defect in the left pubic bone.

The disease in this patient was diagnosed by biopsy from the jaw. It was associated with diabetes insipidus, which was not found in cases previously reported by Farber, Mallory, and Lichtenstein and Jaffe. This, therefore, links the disease still more strongly with Schüller-Christian disease. The patient was treated with a course of roentgenotherapy. Follow-up roentgenograms showed the osteolytic defects in the mandible to be almost completely repaired. There was, however, a considerable enlargement in the skull defect, and the patient was advised to have additional irradiation directed to this area.

DENTAL FINDINGS IN FOUR CASES OF CLEIDOCRANIAL DYSOSTOSIS. Jerry A. Millhon and Louie T. Austin. *American Journal of Orthodontics and Oral Surgery (Oral Surgery Section)*, XXX, 30, January 1944.

Dental findings in such cases are almost always constant. The deciduous teeth erupt normally and are retained longer. The permanent teeth may lose their eruption stimulus and are retained in the jaws. In other instances, only those permanent teeth that follow the deciduous dentition may be involved and fail to erupt. There is no explanation for the lack or partial loss of the eruptive stimulus of the permanent teeth.

In time some of the permanent teeth may erupt, but the general tendency is for them to remain embedded in the jaws. Those persons who either have had their deciduous teeth removed, or have lost them and are wearing artificial dentures, will occasionally need to have permanent teeth removed, because they may erupt later. This more often is due to resorption of the alveolar ridge, bringing the embedded teeth into view. The favored procedure is to remove these unerupted teeth, if and when they make their appearance.

The high incidence of supernumerary permanent teeth, as well as the common occurrence of geminated teeth, is another of the dental peculiarities found in this disease. It signifies that the dental defect begins early in embryonic life. While most of the crowns of the permanent teeth appear to be of normal size, the roots are likely to be stunted or irregularly shaped.

If there are many teeth retained in the jaws, the alveolar ridges are quite thick, giving the appearance of gingival hypertrophy.

The maxilla is generally underdeveloped, and the roof of the mouth has a tendency to be quite narrow and high. The mandible, therefore, appears to be prognathous, which sometimes helps to emphasize a difference in the size of the upper and lower lips.—*Dr. Kurt H. Thoma, Boston, Massachusetts.*

Panadizos Necrosantes del Pulgar (Necrosing Panaris of the Thumb). Héctor A. Ardao. *Boletín de la Sociedad de Cirugía del Uruguay*, XIII, 45, 1942.

In the treatment of necrosing panaris of the thumb, the author prefers to wait for the phalanx to sequestrate, rather than to remove the necrosed bone. With this technique, he has seen many thumbs become normal within five months. The patients go back to work in two months. He presents a report of three cases, with many illustrations.—*León Avila, Jr., M.D., San Salvador, El Salvador.*

Táctica Quirúrgica en los Síndromes Costoescalénicos (Surgical policy with the Scalenus Anterior Syndrome). Abel Chifflet y C. Muñoz Monteavaro. *Boletín de la Sociedad de Cirugía del Uruguay*, XIII, 73, 1942.

This is a review of the symptoms and treatment of the scalenus anterior syndrome. Calling attention to the dangers and possible accidents of the surgical treatment, the authors prefer the anterior approach to the surgical region, as by this route a thorough exploration of the brachial plexus may be more easily made.

The authors state that, although in many cases there is a seventh cervical rib or an overgrown transverse process of the seventh cervical vertebra, these anomalies are not always responsible for the pathology of the region; and that, when the scalenus anterior, fibrous tissue, or scar tissue is found to be the cause of compression, there is no need to touch the rib or transverse process, as this adds unnecessary damage. They present four cases, one of which was of the vascular type; the others were caused by injury to the plexus. In all but one, very good results were obtained.—*León Avila, Jr., M.D., San Salvador, El Salvador.*

Posttraumatic Ossification of the Thigh. Oscar R. Maróttoli. *Boletines y Trabajos de la Sociedad Argentina de Cirugía Ortopédica*, I, No. 2, 1943.

Of the many different names under which this condition is known, the author believes it should be recognized by that of posttraumatic ossification of the thigh, because it refers to the two constant factors,—trauma and ossification. It should not be called tumor, because it does not fit into the pathology of tumors.

While the three cases which the author reports are not many, they have been carefully studied and followed. The histories were similar. All patients were track workers who had suffered rather severe traumata over the anterior or anterolateral aspect of the thigh, which had sent them to bed for a week or more because of pain and the impossibility of walking. In each case, there was immediate swelling of the traumatized region; this sometimes disappeared and reappeared again as a solid mass deep in the anterior aspect of the thigh, or sometimes the original swelling persisted, its consistency becoming harder. The flexion and sometimes the extension of the knee were limited, and the strength of extension was decreased.

All three patients were treated by roentgen ray, but only one, aged forty-eight, obtained definite relief of the symptoms and was able to return to work, with only the mass persisting. The other two patients were not relieved by roentgenotherapy, and were treated surgically by resection of the mass and the application of a hip spica for ten days and two weeks, respectively. Both patients had normal, uneventful postoperative courses, and returned to work completely relieved of all symptoms. The patients were forty-nine and twenty-three years old, respectively.

Roentgenograms taken in all three cases showed a small, irregularly shaped mass on the anterior or anterolateral aspect of the femur over the middle third, which appeared to be united to the shaft of the bone. No change could be seen in the roentgenographic appearance of the bone. There was no osteoporosis or atrophy.

It is interesting to note that the youngest patient showed roentgenographic changes twenty days after

the trauma. Donovan, in his published case, states that the appearance of ossification forty days after trauma is extraordinary.

Photomicrographs show the laminated osseous tissue to be well formed; the bone trabeculae are in intimate relation to the fibrovascular elements, and some include a few muscle fibers. It is important to note the histogenetic interpretation of the process, the absence of cellular cartilaginous elements and of osteoid tissue, and, on the other hand, the abundance of osteoplastic cells whose osteogenetic function must be admitted.

As to the treatment, the author believes the area should be immobilized in a plaster-of-Paris cast as soon as possible, even though the ossification has already appeared, so as to reduce its growth as much as possible. In this state roentgenotherapy is indicated. If the functional impairment persists, surgical resection of the pseudo-osteoma will permanently take care of the situation. The author states that, in both the patients treated surgically, relief was complete; in a short period of time both were able to return to their work completely recovered.—*G. Picazo, M.D., Iowa City, Iowa.*

HYDATID DISEASE (ECHINOCOCCOSIS) MAINLY FROM THE CLINICAL STANDPOINT. I, II. Louis Barnett. *The Medical Press and Circular*, I, 8 and 26, January 5 and 12, 1944.

In these two articles, the author sketches the life cycle of the hydatid parasite, from its worm stage in the intestine of the dog to its cystic stage in sheep or man. Hydatid eggs, when swallowed by the human being or other suitable host, usually hatch out in the upper reaches of the small intestine. The tiny embryos burrow into the intestinal wall until they reach and penetrate into the lumen of a blood, lacteal, or lymph vessel. The blood stream carries them to various organs of the body which serve as filters: the liver (66 per cent.), the lungs (approximately 23 per cent.); the remaining 11 per cent. pass through the lung capillaries to the systemic arterial circulation, the third filter, where they become blocked in the capillaries of muscle and subcutaneous fascia (4 per cent.), bones (2 per cent.), kidneys (2 per cent.), spleen (1 per cent.), brain (.5 per cent.), orbit, thyroid, breast, pancreas, uterus (1.5 per cent. in all).

Cysts located in intramuscular and subcutaneous fascia are usually multilocular and multivesicular. The treatment is complete excision, including the adventitia.

Hydatids of bone are slow and insidious, with little clinical manifestation. Myriads of small exogenuously budding vesicles infiltrate the bone tissue. The condition is generally recognized only in time for amputation of the limb; spontaneous fracture sometimes occurs.

Correct diagnosis can easily be missed. Pathologists agree that a definite complement fixation, or a well-marked Casoni skin reaction, is positive proof in the majority of cases. Hydatid material may be coughed up, vomited, or excreted. Whole or broken cysts or fragments of membrane are easy to recognize. Even a single scolex, or hooklet, seen under the microscope, is pathognomonic. Diagnostic tapping should be resorted to only when the cyst is actually exposed in the field of operation; otherwise, rupture of the cyst, leakage, and suppuration may result.

Hydatid disease is considered the national malady of Uruguay and Argentina. It is very prevalent in Australia, New Zealand, and South Africa. Iceland has reduced its incidence of the disease through preventive measures. Other regions where the echinococcus granulosus or taenia echinococcus flourishes are Syria, Greece, Sardinia, Italy, Dalmatia, the Balkans, Algeria, and Tunisia.

In countries where the disease is prevalent, lack of cooperation of dog owners is largely responsible. Dogs should be dosed periodically with vermifuge medicine, and prevented from feeding upon raw cyst-bearing offal of sheep and other stock animals, a practice which only preserves the vicious circle.

The author recommends the writings of Prof. F. Dévé, of Rouen, for study.

THE USE OF REFRIGERATION IN AMPUTATIONS AND PERIPHERAL VASCULAR DISEASE. E. Everett O'Neil. *The New England Journal of Medicine*, CCXXX, 209, February 24, 1944.

This is a well-balanced article. The method is one of combined ligation by means of a tourniquet and refrigeration. The details are explained and illustrated. The necessary degree of anaesthesia is reached in about two and a half hours. It was found, however, that the tourniquet could safely be continued as long as ten or twelve hours. This sometimes is of great advantage, because the enhancement of the patient's comfort results in a great gain in his general condition, and the amputation is proportionately better borne.

Most wounds were tightly closed, and primary healing was the rule. Whereas, in the period 1930 to 1939, amputations for major gangrene in patients of poor risk had shown a mortality of 53 per cent. under conventional methods, this high mortality was reduced to 32 per cent. in a series of fifty similar cases of poor risk.

In a small series of cases of circulatory insufficiency, refrigeration alone was employed, but, while there were gratifying results in some instances, there were disappointments in others. No conclusion is to be drawn from this limited experience. However, the author is certain that refrigeration in major amputations is a sound surgical procedure. In one hospital, where refrigeration was used in fifty unselected cases, there was a mortality of only 13 per cent. It is noted that, in the presence of frank gangrene with or without sepsis, refrigeration retards the progress of both processes.—*Paul P. Swett, M.D., Bloomfield, Connecticut.*

PRINCIPLES OF TREATMENT IN PERIPHERAL NERVE INJURIES. Max T. Schnitker. *Northwest Medicine*, XLIII, 5, 1944.

The author describes in adequate detail the principles governing successful nerve repair, and urges early suture in the absence of infection, as it is the growth of fibrosis that blocks many otherwise successful nerve anastomoses. The use of the sulfonamides or of penicillin is very valuable in contaminated or infected fields.

End-to-end anastomosis is imperative, if this can possibly be accomplished. The two scarred end bulbs are sutured together solidly with the nerve in optimum relaxation and the extremity properly flexed; the nerve is then gradually lengthened as the extremity is straightened during several weeks' time, until maximum stretching of the nerve has taken place. In a secondary operation, the nerve bulbs are resected, and an end-to-end anastomosis of healthy nerve fibers is carried out. It may be necessary to transplant the nerve bed, or even to shorten the limb by resection of bone. Radical splinting is sometimes sufficient to keep the ends together. Every effort should be made to forestall fibrous growth in the sutured area.

Tantalum wire .003 of an inch in diameter is an excellent suture material; fine silk or nerve "glue" (plasma or acacia) is sometimes used. Wrapping the region of the anastomosis with tantalum foil, .00025 of an inch in thickness, will protect the nerve anastomosis against invading scar tissue from without; it should not be placed directly beneath atrophic scarred skin as it tends to break through the scar easily.

—Charles Lyle Hawk, M.D., Los Angeles, California.

HEALING OF RADIATION FRACTURES OF THE NECKS OF THE FEMORA, WITH A REPORT OF A CASE. Stuart P. Barden. *Radiology*, XLI, 389, 1943.

The author reports a case of postirradiation fractures of the necks of both femora in a woman patient, sixty-five years of age. Two months before being seen by the author, she had received radium treatment for a basal-cell epithelioma of the urethra. Upon admission to the Hospital, roentgen-ray therapy was prescribed. It was directed to the center of each femoral neck. One year later, the patient complained of pain in the left hip. Roentgenograms revealed a fracture through the neck of the left femur. This was thought to be the result of metastasis, and further irradiation was given. The fracture healed, and the diagnosis was changed to that of postirradiation fracture.

Two years later, the patient experienced pain in the right hip. An early radiation fracture of the neck of the right femur was discovered.

The later occurrence of the fracture of the neck of the right femur was thought to be due to the lesser amount of irradiation given it. Both fractures were treated with bed rest and limited (Buck's) traction.

The patient died a year after the second fracture; metastatic pulmonary lesions had been seen in roentgenograms taken a few months previously.

Most postirradiation fractures heal with difficulty, and then only by fibrous union. They are apt to occur one to five years from the date of irradiation. The majority have been in the femoral necks in patients treated for carcinoma of the uterine cervix. The patient is cautioned, therefore, during treatment, to turn the toes inward and the heels outward, thereby rotating the femora internally and throwing the femoral necks further away from the sources of radiation.

SPONDYLOLISTHESIS: A GENERAL CONSIDERATION WITH EMPHASIS ON RADIOLOGIC ASPECTS. A. C. Galluccio. *Radiology*, XLII, 143, 1944.

Prespondylolisthesis is the term used to indicate a defect in the continuity of the pars interarticularis of the neural arch of a vertebra, in the sense of a zone of inadequate ossification. This may be unilateral or bilateral. With the occurrence of actual displacement, the condition becomes spondylolisthesis.

Various authors have placed the incidence of spondylolisthesis at from 5 to 6 per cent. Fifty per cent. of the cases are seen in the third and fourth decades; 76 per cent. are in males; 80 per cent. occur between the fifth lumbar and the first sacral segment; and 50 per cent. show Grade I displacement, according to Meyerding's classification.

Predisposing causes are lumbosacral articulations in the sagittal plane, and a steep lumbosacral angle.

The body of the vertebra, the pedicles, and the superior articular processes are displaced forward, leaving behind the inferior articular processes, the laminae, and the spinous process. Protrusion or herniation of the disc is rarely associated with this condition; although, if the displacement is great, the disc may become displaced and undergo progressive degeneration.

Meyerding has suggested that an injury during birth may produce a bone infarct, with subsequent softening, and later a picture strongly suggestive of osteochondritis. Whether the defect of prespondylolisthesis is developmental, from failure of separate centers of ossification to unite, or is traumatic in origin, is undecided. Hitchcock, examining ninety fetuses, failed to find more than three centers of ossification. The isthmic region remains cartilaginous until after birth. He found that moderate hyperflexion readily fractured the neural arch in the lower lumbar region, usually bilaterally, but if the hyperflexion was com-

bined with lateral bending and some torsion, the fracture was unilateral. Flexion applied during delivery or shortly after birth may produce fracture, with subsequent union by cartilage or fibrous tissue and development of a pseudarthrosis.

Ten per cent. of the cases are asymptomatic. Most patients have low-back pain. The diagnosis requires good roentgenograms, with the central ray directed over and in the plane of the defect. Right and left oblique views are of the utmost importance.

A lateral view, taken in a standing position, may show an increased slippage. The lesion may be demonstrable in only one of several views taken,—that one in which the axis of the central ray coincides with the plane of the defect; hence the importance of several projections. The most important are anteroposterior, right and left oblique, and direct and accurate lateral.

Adequate treatment includes spine fusion. Conservative treatment will be followed by symptomatic relief in about one-third of the cases.—*Edward N. Reed, M.D., Santa Monica, California.*

Técnica do Professor Godoy Moreira para a osteosintese do colo do femur. Simplificação instrumental (Prof. Godoy-Moreira's Technique of Osteosynthesis of the Neck of the Femur. Instrument Simplification). Renan Azzi Leal e Edmundo Batalha. *Revista Brasileira de Ortopedia e Traumatologia*, IV, 55, 1943.

Prof. Godoy-Moreira described a special stud-bolt screw for fixation of fractures of the neck of the femur in the July 1940 issue of *The Journal of Bone and Joint Surgery*. In the operative technique, a special attachment for mounting the drill and burr and an electric motor were used. In the present article, two assistants in Prof. Godoy-Moreira's Clinic describe a method which simplifies the technique of introduction of the stud-bolt screw. The screw itself remains without change. Instead of the electric motor and the special attachment, a hand drill is used. The operative technique is very much simplified. The article illustrates the instruments used and presents roentgenograms showing the Godoy-Moreira screw well placed in three reduced fractures of the neck of the femur.—*Emanuel B. Kaplan, M.D., New York, N. Y.*

Costilla Cervical Supernumeraria. (Supernumerary Cervical Rib). Pedro Antonio Landa y Carlos A. Botto. *La Revista de Medicina y Ciencias Afines*, V, 494, 1943.

This is a good article on cervical rib, with a presentation of two cases illustrating the two types as to symptoms: the silent, and the type with nerve symptoms. The first case was a man, aged thirty, in whom the condition was diagnosed incidentally when he was having a physical examination; the diagnosis was confirmed roentgenographically. The other case was a woman, aged forty, who had had pain, paraesthesia, and weakness for one year, coming on after she had done heavy lifting. The diagnosis was confirmed roentgenographically in this case also. Bilateral long cervical ribs were present.

The entire subject is discussed thoroughly. Cervical rib was first described in 1742 by Hunauld, and the first clinical case was diagnosed in 1818 by Cooper. Various complicated classifications have been made and are presented by the authors. The embryology of cervical rib is discussed. In only 5 to 10 per cent. of the cases, according to Saiton, are symptoms present. The treatment of choice is operative removal of the cervical rib, a technically difficult procedure. If the surgeon lacks the courage, or the patient refuses operation, diathermy or neurolysis may be used.—*Major Louis W. Breck, M.C., Camp Swift, Texas.*

Osteoclisis. Nueva Técnica Para La Transfusión de Sangre y Liquidos. (Osteoclysis. A New Technique for Transfusion of Blood and Fluids.) Guillermo Benavides Uribe. *Revista Mexicana de Cirugía, Ginecología y Cáncer*, XI, 137, 1943.

This article deals with the injection of blood and other fluids into the bone marrow of the spongy bones, a technique which the author calls osteoclysis to correspond with other similar terms, such as venoclysis. The advantage of the method is that it can be used in difficult cases,—as in children or adults with small veins. The bone usually employed is the sternum. Local anaesthesia is used for the skin, and a heavy trocar-type needle is used for the puncture. Considerable force is sometimes necessary, but there is little danger of perforating the mediastinum, since the posterior wall of the sternum is heavier than the anterior wall. The usual rate of infusion with citrated blood is five cubic centimeters per minute in an adult, and 1.5 cubic centimeters per minute in a small child.

The reviewer chose this article for review because it shows the absorptive power of bone marrow and makes one reflect on its resistance to trauma. The author of the paper quotes the original American references on this subject.—*Major Louis W. Breck, M.C., Camp Swift, Texas.*

Osteodystrophia Fibrosa Cystica and Juvenile Hyperthyroidism. J. E. Jacobs. *Southern Medical Journal*, XXXVI, 668, 1943.

Two cases of osteodystrophia fibrosa cystica, associated with pathological fracture, hyperthyroidism, and retarded sexual development, are reported.

In the first patient, a girl twelve years old, roentgenograms showed a diffuse osteoporosis with cystic areas involving the right femur, from the trochanters to the midshaft, with a pathological fracture at this site, as well as the midshaft of the left tibia and the right ulna and radius. The skull and pelvis showed only osteoporosis. Five months after admission to the Hospital, a subtotal thyroidectomy was done, because of delayed union of the fracture and continuance of the thyroid symptoms. Twenty-five months after the fracture and twenty months after the thyroidectomy, the typical symptoms of hyperthyroidism had diminished, ovarian function was no longer suppressed, the patient walked without a limp, and roentgenograms of the bones revealed only slight osteoporosis.

Hyperparathyroidism was ruled out in this case, as calcium and phosphorus determinations consistently showed normal levels, and examination of the thyroid tissue removed exhibited no parathyroid tissue.

In the second patient, a boy twelve years old, cystic areas involved the entire greater trochanter and neck of the femur on the left. Five successive pathological fractures occurred, four in the hip region, and one in the upper third of the tibia. The tibia was osteoporotic, but non-cystic.

Thyroidectomy was steadily refused for this patient by his parents. When last seen, the boy was ambulatory on crutches, weighed 133 pounds, and had a pulse rate of 120.

NOTES ON THE DIAGNOSIS OF HERNIATED NUCLEUS PULPOSUS IN THE LOWER LUMBAR REGION. R. Glen Spurling and T. Campbell Thompson. *Surgery*, XV, 387, March 1944.

Approximately 60 per cent. of herniations of the nucleus pulposus in the lumbar region of the spine can be diagnosed by carefully elicited history and physical examination. In the remaining 40 per cent., such lesions can be demonstrated only by exploratory operation or by myelography. Spurling and Thompson have discussed the contra-indications to the use of the usual mediums of lipiodol, thorotrast, or air for visualization of a defect in the spinal canal which might be produced by herniation of a disc. They recommend a new myelographic medium, which, they state, combines the desirable qualities of lipiodol and thorotrast and is more easily removed by aspiration. This material is called pantopaque. Three cubic centimeters of pantopaque are injected. The specific gravity of pantopaque is greater than that of spinal fluid; hence, as the head of the patient is raised on a tilting table, the pantopaque seeks a lower level in the spinal canal.

Spot films are made at each disc level, and when a defect is noted, oblique or lateral films are also taken at this level. After completing the study, the needle, which has been left in position during the course of the examination, is introduced about two millimeters farther into the spinal canal, the tilting table is adjusted until the opaque material is centered about the point of the needle, and the pantopaque is slowly and gently aspirated. The majority of this material can be withdrawn. Any small remaining amount will subsequently be absorbed. Spurling and Thompson state that experience with approximately 200 pantopaque myelograms showed this to be a most satisfactory method for visualizing the spinal canal.—*Edward L. Compere, M.D., Chicago, Illinois.*

STUDIES ON TRAUMATIC SHOCK. II. THE RESTORATION OF BLOOD VOLUME IN TRAUMATIC SHOCK. Everett Idris Evans, G. Watson James, III, and M. J. Hoover. *Surgery*, XV, 420, March 1944.

This is the second paper in a series of studies of traumatic shock. The authors have demonstrated in a series of human case studies that, after a patient has suffered trauma accompanied by blood or plasma loss, severe enough to reduce the blood volume from 25 to 40 per cent., there is a very slow restoration of plasma volume. Several days may elapse before the plasma volume returns to a normal level. A comparison of their studies with those of other workers has led to the conclusion that, in the human subject, restoration of plasma volume is much slower after traumatic shock than after simple hemorrhage without shock. The restoration of blood volume after traumatic shock and hemorrhage is accomplished by the withdrawing of fluids from other tissue into the blood stream. These extra-vascular fluids contain a far lower content of protein than that of normal plasma, and of course they fail to replace the red cell loss. Complete recovery from such shock can only be achieved through the slow process of building up the plasma protein and regeneration of red blood cells, or through the intravenous administration of adequate amounts of whole blood which will replace both red blood cells and plasma protein.—*Edward L. Compere, M.D., Chicago, Illinois.*

ROENTGENOGRAPHIC DIAGNOSIS OF TORSIONAL DEFORMITIES IN TUBULAR BONES. Henry Milch. *Surgery*, XV, 440, March 1944.

In the treatment of fractures or correction of deformity by means of osteotomy, the surgeon and the roentgenologist have been concerned in most instances with the problems of length, alignment, or angulation. Failure to recognize the presence of rotation has undoubtedly accounted for some of the difficulty experienced in the treatment of spiral or malleolar fractures of the tibia, fractures of the femoral neck, or supracondylar fractures of the humerus. Excessive rotational deformity may be difficult to demonstrate in the roentgeno-

gram, but it should be corrected as a most important step in treatment. In order that rotation may be adequately appraised and subsequently corrected, it is necessary that the attending surgeon become thoroughly familiar with the roentgenographic projections of normal prominences on the long bones. Milch has called attention to the presence of such normal anatomical prominences in the long bones of all four extremities, and has illustrated their roentgenographic appearance in critical positions. Comparison of true anteroposterior and lateral films, including the complete shaft of the bones of both the normal and the injured extremity, must be made and studied in the most careful detail. By comparing the position of the anatomical prominences of the normal bone with those of the injured bone, it may be possible to recognize and to correct the torsional deformity.—*Edward L. Compere, M.D., Chicago, Illinois.*

INTERNAL FIXATION OF FRACTURES OF THE PATELLA WITH COTTON SUTURE MATERIAL. Lyon K. Loomis. *Surgery*, XV, 602, April 1944.

Treatment of fracture of the patella has varied during the past few years in more ways than merely a difference in the choice of suture materials. A trend in the direction of excision of varying amounts of the fragments has been noted. Loomis, however, has continued to favor open reduction with fixation of the fragments. He has not used wire, because of the theoretical factor of electrolysis and disintegration of the metal; he has favored cotton as a suture material because it may be tied rather than twisted, and he has noted no joint reactions as a result of the use of this suture material. Eleven patients have been treated by use of cotton suture with uniformly good results.—*Edward L. Compere, M.D., Chicago, Illinois.*

THE ASSOCIATION OF THROMBOPHLEBITIS WITH HEMATOGENOUS BONE INFECTION. Abraham O. Wilensky. *Surgery*, XV, 653, April 1944.

This is a brief case report of a hematogenous bone infection which spread outward from the bone to involve an adjacent vein, draining the area, and producing thrombophlebitis. The patient had been treated for an infected bone cyst of the tibia in March of 1931. There was a recurrence of pain and evidence of infection in September, 1936, again requiring surgery. In May of 1943, this same patient developed a dento-alveolar infection which suppurated and was incised and drained. Almost immediately thereafter, there was another recurrence of the inflammatory process in the tibia. On this occasion the inflammation spread outward from the tibia, producing thrombosis in the adjacent veins. X-ray therapy was used, and complete healing resulted.—*Edward L. Compere, M.D., Chicago, Illinois.*

PYOGENIC COXITIS. II. INDICATIONS FOR SURGICAL TREATMENT IN RESIDUAL AND CHRONIC STAGES AND END-RESULTS OF RECONSTRUCTION IN 53 PATIENTS. Paul H. Harmon and Carroll O. Adams. *Surgery, Gynecology and Obstetrics*, LXXVIII, 497, May 1944.

Eighty-two reconstructive surgical operations have been performed by the authors on fifty-three patients suffering with residual disease, deformity, or both, from chronic hip-joint infection. Based on the results obtained, the authors give the indications for and the type of surgical procedure indicated in chronic suppurative coxitis. First and foremost, an attempt must be made to eliminate all chronic drainage by the usual localization and removal of sequestra, chronic bone abscesses, and epithelialized sinuses. For special conditions, the following reconstructive procedures are recommended:

1. *For malposition.* Where joint stability is fair, a subtrochanteric osteotomy will improve stability and give functional increase of leg length up to one inch. When the mechanics of muscle pull in the presence of incipient or dislocated hip are considered, the downward shift of the greater trochanter is the mechanical equivalent of performing an abduction osteotomy. Improvement in gait, however, was not forthcoming in three cases reported.

2. *Unilateral hip-joint instability.* In the adult, the only method of obtaining stability is by arthrodesis. In the juvenile group, the shelf operation is the treatment of choice.

3. *Unilaterally ankylosed hips.* Motion can be restored by various types of arthroplasty, with an expectancy of reactivating the infection in 13 per cent. of the cases. Several criteria are listed by the authors as prerequisites before arthroplasty should be attempted. These rules also have been applied in cases of bilateral ankylosis.

4. *Painful hips.* This is a probable outcome of all movable diseased hips in later years. It can best be dealt with either by arthrodesis or arthroplasty.

5. *Unequal leg lengths.* This condition is treated in the usual way by leg shortening, leg lengthening, or epiphysiodesis.

In general, positional correction by osteotomy, and arthrodesis for stability and removal of pain are more satisfactory than the arthroplastic procedures. The cases of patients with bilaterally damaged hips make up an appalling group and need further intensive study.—*Carroll B. Larson, M.D., Boston, Massachusetts.*

TRANSLOCATION OF THE PERONEUS LONGUS TENDON FOR PARALYTIC CALCANEUS DEFORMITY OF THE FOOT. William H. Bickel and John H. Moe. *Surgery, Gynecology and Obstetrics*, LXXVIII, 627, June 1944.

The authors have described an operative procedure for the relief of paralytic calcaneal deformity of the foot, resulting from poliomyelitis in thirteen patients. The method consists of translocating the peroneus longus tendon by sliding it intact around the lateral border of the heel into a groove in the midline of the os calcis, in an attempt to improve upon the results obtained where the peroneal tendon is caught and transplanted into the tendo achillis.

In this series there were three poor results, two fair results, four good results, three very good results, and one excellent result.

The authors concluded that the best results were obtained when the operation was done on patients who had slight remaining power in the gastrocnemius muscle, and fair or better power in the transposed peroneal muscle. It was their opinion that the results were strikingly better than if the peroneal tendon had been cut and then transplanted into the tendo achillis.—*Carroll B. Larson, M.D., Boston, Massachusetts.*

FRACTURES OF THE NECK OF THE FEMUR. AN ANALYSIS OF 157 INTRACAPSULAR AND EXTRACAPSULAR FRACTURES. Irwin E. Siris and John D. Ryan. *Surgery, Gynecology and Obstetrics*, LXXVIII, 631, June 1944.

This study reports the authors' management of fifty-seven intracapsular fractures and one hundred intertrochanteric fractures of the neck of the femur. The majority of cases were treated by internal fixation with a cannulated three-flanged nail; the technique is described.

In forty-seven of the intracapsular fractures, fixation was with a Smith-Petersen nail: in five with a Smith-Petersen nail and Hawley bar. The mortality up to the twenty-first postoperative day was 9.6 per cent. The deaths occurred in patients first treated in traction for twelve, three, two, thirty-seven, and eight days, respectively. In five patients, the nail was extruded from the proximal fragment; two cases presented eventual aseptic necrosis of the head. In one patient treated for a low transcervical fracture, the nail straddled the fragments for a distance of one-half to three-quarters of an inch, one year after nailing; a fibular graft was used to bridge the hiatus, and union followed.

Of the extracapsular fractures of the neck of the femur, the over-all mortality was 22 per cent., compared with 8.7 per cent. for intracapsular fractures. Twenty-seven cases were treated with Russell traction, with a mortality of 7.4 per cent. Seventy-three patients were operated upon; in sixty-eight internal fixation was used, and in five external fixation (Roger Anderson half pins); of these, thirty-four had been in Russell traction three to fifteen days, and in this group the mortality was 13 per cent. The five treated by external fixation died. Sixty-one were treated with a Smith-Petersen nail, with or without the Hawley bar; the mortality was 19.6 per cent. In the follow-up, one case of pseudarthrosis was reported in an intertrochanteric fracture. The authors warned that the method is fraught with complications, and in their hands the results were poor.

From this analysis, it was concluded that the treatment of choice for intracapsular fractures is immediate insertion of a Smith-Petersen three-flanged nail or a similar device. For intertrochanteric fractures in the aged, the authors favor the Moore-Blount blade plate; they believe it will obviate the difficulties they experienced with the Smith-Petersen nail and Hawley bar.—*Carroll B. Larson, M.D., Boston, Massachusetts.*

A THREE PIN METHOD FOR TREATMENT OF SEVERELY COMMINUTED FRACTURES OF OS CALCIS. Gerald G. Gill. *Surgery, Gynecology and Obstetrics*, LXXVIII, 653, June 1944.

Since August 1942, a method has been developed for treatment of fractures of the os calcis. The principle of the treatment depends on a distracting force in three directions to gain length of the os calcis, restore tuber angle, and open the subastragalar joint. This is accomplished by the insertion transversely of three Steinmann pins, five thirty-seconds of an inch in diameter, through the posterior superior angle of the os calcis, the neck of the astragalus, and the cuboid, respectively. The patient is placed on his abdomen on a Bell table, with his foot supported in a suspended position by an apparatus with windlass arrangement.

After the reduction has been accomplished, it is maintained by incorporating the pins in a light nonpadded cast, with the ankle free and the dorsum of the foot exposed.

No statistics concerning number of cases or end results are given. Many patients are returned to active work in twelve weeks. There has been a surprising lack of oedema and pain in the foot. The author states that it is probable that at least 50 per cent. of the patients will need triple arthrodesis in the future; but in his opinion the results will be better after triple arthrodesis in fractures treated initially by this method, than if any other technique had been used.—*Carroll B. Larson, M.D., Boston, Massachusetts.*

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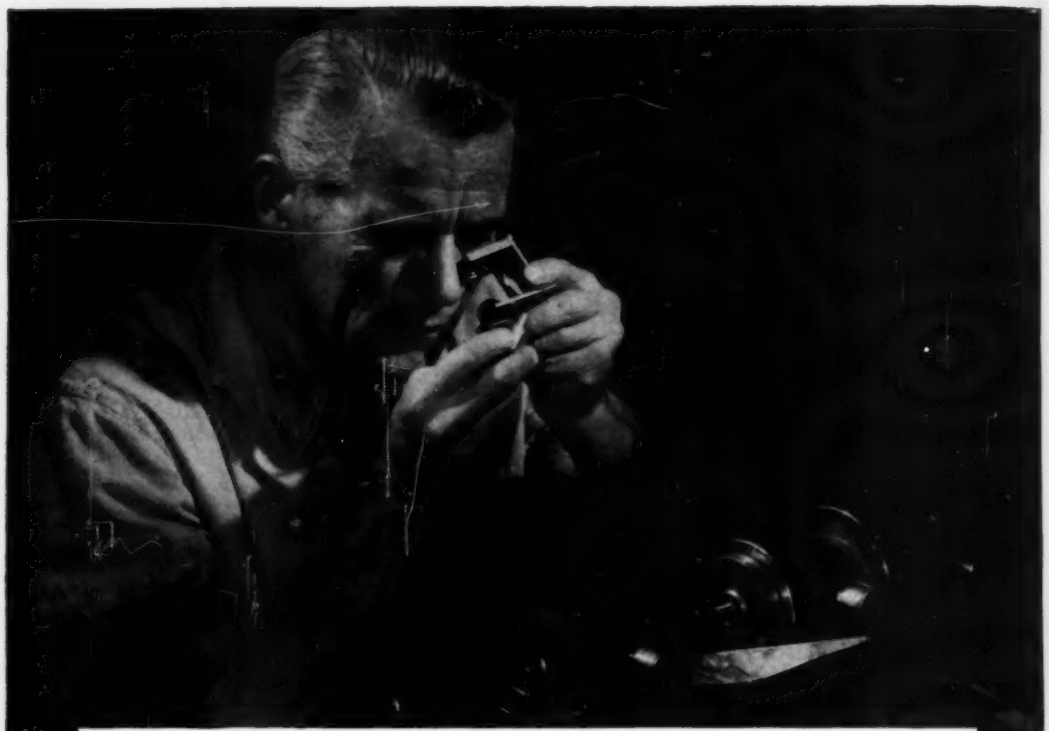

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